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Eocene shallow marine foraminifera from subsurface sections in the Yufutsu-Umaoi district, Hokkaido, Japan

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Abstract. In subsurface sections of the Yufutsu-Umaoi district, Hokkaido, northern Japan, three Eocene benthic foraminiferal assemblage zones were defined in the Ishikari Group and the overlying Poronai Formation. They are in ascending order: *Evolutinella subamakusaensis-Haplophragmoides crassiformis* Assemblage Zone, *Globocassidulina globosa-Cribroelphidium sorachiense* Assemblage Zone, and *Bulimina schwageri-Angulogerina hannai* Assemblage Zone. Assemblages characterizing each zone indicate the littoral to the inner sublittoral, middle sublittoral, and outer sublittoral paleobathymetric zones, respectively. A foraminiferal fauna in the upper bathyal zone was also identified based on reinterpretation of previous studies. It is composed of calcareous species such as *Gyroidina yokoyamai* and *Plectofrondicularia packardii*. Abundant occurrences of agglutinated foraminifera in shallower paleoenvironment suggest brackish and related stratified-water paleoenvironments caused by freshwater input into an embayment called the "Poronai Sea". Such stratified conditions in coastal shallow marine areas may have formed oxygen-depleted zones as suggested in the previous study. These data and their paleoenvironmental implications are expected to furnish a basis for further consideration on geohistory of the Paleogene formations and also on the Eocene foraminiferal fauna of the northwestern Pacific.

Key words: Eocene, foraminifera, Ishikari Group, paleoenvironment, Poronai Formation

Introduction

The purpose of the present paper is to delineate the Eocene shallow marine foraminiferal assemblages from borehole sections in the Yufutsu-Umaoi district, southern Ishikari Plain, Hokkaido, northern Japan; to consider depositional environments; and to describe paleobathymetric distributions of benthic foraminifera.

Studies of the Japanese Paleogene smaller foraminifera began with the report of Yokoyama (1890). Following him, studies have been conducted mainly on the fossils from the Ishikari Group and the overlying Poronai Formation in the coalfield regions of Hokkaido and from the Kyoragi Formation of the Hondo Group in the Amakusa Islands, Kyushu, southwestern Japan (e.g. Asano, 1952, 1954, 1958, 1962; Asano and Murata, 1957; Fukuta, 1962). Paleogene foraminiferal faunas at various localities in Hokkaido were studied by Kaiho (1983, 1984a, b, c) who reported on their stratigraphic and paleogeographic distributions. Kaiho (1992b) also conducted a comparative taxonomic study of the Paleogene foraminiferal faunas from Hokkaido with other regions of the world, and recognized some species from the Poronai Formation as an "intermediate-water" fauna. His "intermediate-water" has a depth range of 100–1000 m (Kaiho, 1992b). This range almost corresponds to three bathymetric zones in the modern northwestern Pacific coast of Japan according to the compilation of Akimoto and Hasegawa (1989). They are the outer sublittoral zone (approximately 70 to 180 m), upper bathyal zone (180 to 550 m) and upper middle bathyal zone (550 to 900 m). However, correlation of each paleobathymetric zone with the foraminiferal fauna was not discussed in the report.

Deep marine foraminiferal assemblages generally include elements transported from shallower marine environments by bottom currents and/or gravity currents (Zalesny, 1959; Ingle, 1980). This means that the deep marine fauna can be recognized only after the shallower marine fauna has been identified. However, little is known about the Paleogene shallow marine foraminiferal faunas in

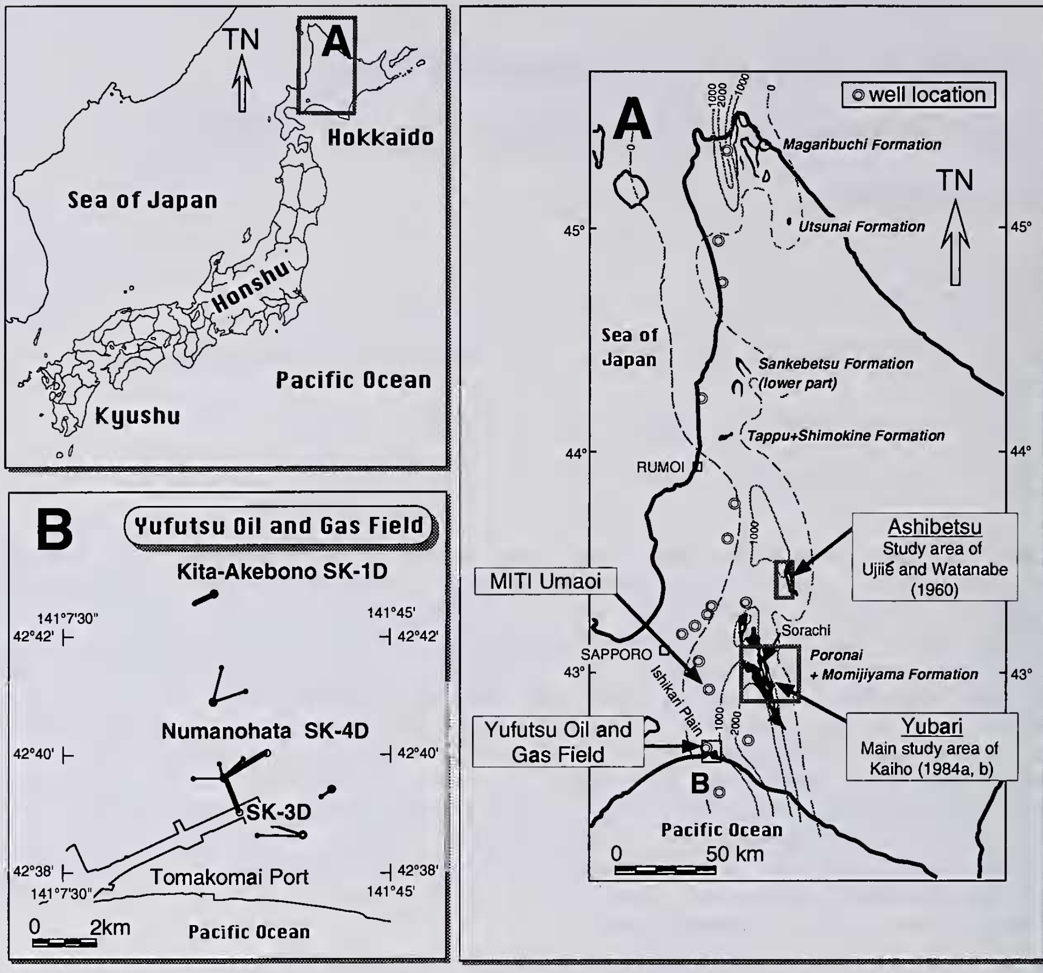


Figure 1. Index map showing the well sections studied. A = Dashed lines denote isopachs of the Poronai Formation and its equivalents drawn in a 500-meter thickness interval (Japan Natural Gas Association and Japan Offshore Petroleum Development Association, 1992). Double circles indicate the sites of the wells controlling the isopachs. Dark areas show surface distribution of the Poronai Formation, Momijiyama Formation, and their equivalents after Yamada *et al.* (1982). B = Location of the wells in the Yufutsu oil and gas field. Double circles indicate the sites of the wells, and small dots indicate the bottom of the wells. Thick lines indicate wells used in this study.

Hokkaido. The material I examined in the present study is from marine strata (Poronai Formation) which grades from nonmarine coal-bearing formation (Ishikari Group), representing a transgressive phase, and thus provides an opportunity to study the shallow marine fauna. Moreover, because paleoenvironments of the Paleogene in Hokkaido and the northwestern Pacific region have not been well studied, data on paleobathymetric distribution of foraminifera examined in the present study are expected to provide a basis for further studies in the region.

Japan Petroleum Exploration Co. Ltd. (JAPEX) has been exploring oil and natural gas in the southern Ishikari Plain. Since the discovery of the Yufutsu oil and gas field, whose reservoir is in the Cretaceous granitoids and Paleogene conglomeratic formations, many wells have been drilled penetrating the Paleogene rocks, namely, the Ishikari Group and the overlying Poronai Formation (Yufutsu Research Group of JAPEX Sapporo *et al.*, 1992; Fujii and Moritani, 1998; Kurita and Yokoi, 2000). The present study was conducted on three well sections in the Yufutsu oil and gas field, Numanohata SK–3D, Numanohata SK–4D and Kita-Akebono SK–1D. In addition, the well MITI Umaoi, drilled in the Umaoi Hills about 25 km north of the Yufutsu oil and gas field, was also investigated (Figure 1; MITI = Ministry of International Trade and Industry). The present study refers to the area including these wells as the "Yufutsu-Umaoi district".

Geological setting

The middle Eocene Ishikari Group crops out in the hilly areas of the Yubari and Sorachi coal fields (Kaiho, 1983; Iijima, 1996). It is composed of alternating marine and nonmarine formations. Thick coal beds are present in the nonmarine part.

The Poronai Formation, which overlies the Ishikari Group, outcrops in the Yubari and Ashibetsu districts (Figure 1). It is composed mainly of massive siltstone that intercalates with acidic tuff beds in the middle to upper part (Kaiho, 1983). The geologic age of the Poronai Formation in the Yubari district was determined by calcareous nannofossils to be late Middle Eocene to Late Eocene in age (Okada and Kaiho, 1992). Broad distribution of the Poronai Formation and its equivalents in the subsurface of the Ishikari Plain is confirmed by boreholes (Figure 1A: Japan Natural Gas Association and Japan Offshore Petroleum Development Association, 1992; Japanese Association for Petroleum Technology, 1993).

Many researchers have discussed the stratigraphic relationship between the Ishikari Group and the overlying Poronai Formation since Yabe (1951) proposed their heteropic facies (synchronous) relationship (Asano, 1952, 1954; Saito, 1956; Sasa, 1956; Sasa *et al.*, 1953; Yabe and Asano, 1957; Uchio, 1961, 1962), although no conclusive interpretation has yet been drawn. The present study assumes a conformable contact between them in the borehole sections studied here. This interpretation is based on transitional characteristics of lithology as discussed later.

Lithostratigraphy of study sections

Lithologic columns of the study wells are presented in Figure 2. Lithologic descriptions of each section are based on the wellsite survey of ditch cuttings. Numbers shown on the left of each column are drilling depths from the surface. All study wells of the Yufutsu oil and gas field are deviated, therefore drilling length differs from true thickness of formation. In addition, formation contacts are placed on the basis of wireline logs whose depths may not match the drilling depths measured by the length of drill pipes.

Interpretations of wireline logs prove that the uppermost part of the Poronai Formation is missing because of a fault in Numanohata SK-3D. Also because of a fault, an interval from the lowermost Poronai Formation through the upper part of the Ishikari Group is repeated in Numanohata SK-4D.

After correcting for well deviations and formation dips, the true thickness of the Poronai Formation in the Yufutsu oil and gas field is estimated as approximately 450 m to 500 m, while in the vertical well MITI Umaoi, it is approximately 780 m.

Lithology of the Ishikari Group and the Poronai Formation in the study well sections is similar. Its vertical changes are as follows in ascending order; basal conglomerate bed, medium to finer sandstones with siltstone beds, and finally siltstones and mudstones. The basal conglomerate of the lowermost part of the Ishikari Group grades upward, intercalating with finer-grained sediments, into an alternation sequence of medium to fine sandstone beds and olive-black to olive-gray siltstone beds. Coal beds are frequent. The sandstone and siltstone beds of the uppermost Ishikari Group grade upward into the siltstone and mudstone of the Poronai Formation, which contains marine fossils such as foraminifera, ostracods, dinoflagellates, and fragments of mollusks. The Poronai Formation consists mainly of olive-gray or dark gray siltstone and mudstone. Tuff and sandstone beds intercalate in the upper part of the formation in Kita-Akebono SK-1D and MITI Umaoi, where the formation is thicker than in the other well sections. The Upper Oligocene Minaminaganuma Formation unconformably overlies the Poronai Formation in the Yufutsu-Umaoi district (Kurita and Yokoi, 2000). The Lower Oligocene Momijiyama Formation (Kaiho, 1983; Kurita and Miwa, 1998), which overlies the Poronai Formation in the Yubari district, is not present in the study area.

The upward fining of the sediments without any break from the Ishikari Group to the lower part of the Poronai Formation in the Yufutsu-Umaoi district suggests a transgressive sequence.

Samples and methods

All borehole samples used in the present study are ditch cuttings. Borehole conditions during drilling were good, and contamination caused by the caving was negligible. Samples were taken every 20 m; additional samples were taken from the siltstones in the coal-bearing formation. In the Kita-Akebono SK-1D well, samples were collected at every 10 m for most of the studied interval. A total of 173 samples were examined.

All samples were oven-dried. Subsamples of about 100 g were soaked in boiled sodium sulfate supersaturated solution for about three hours. After removing excess solution, soaked samples were left more than three days. Then they were wet sieved through a 125 μm-opening screen. All specimens in the residues were picked and identified under a binocular microscope.

Percentages of planktonic species, agglutinated species, and calcareous benthic species, and total populations were determined for these samples. Diversity, species richness (number of species) as well as "Simpson's Index for Diversity" (SID: Simpson, 1949) were used to analyze the

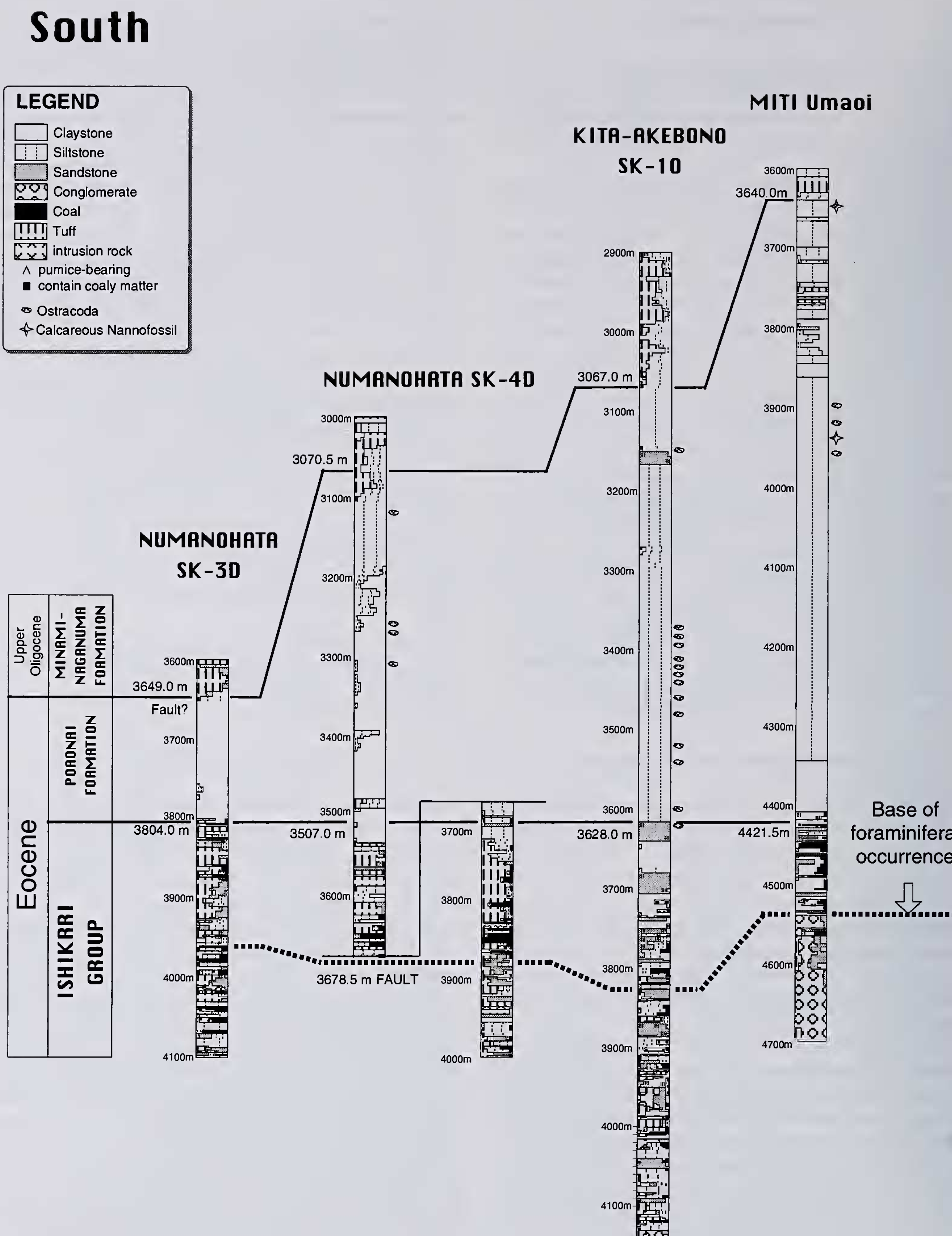


Figure 2. Stratigraphic correlation based on lithostratigraphy and wireline geophysical loggings of the study wells. Well sections are arranged at the base of the Poronai Formation.

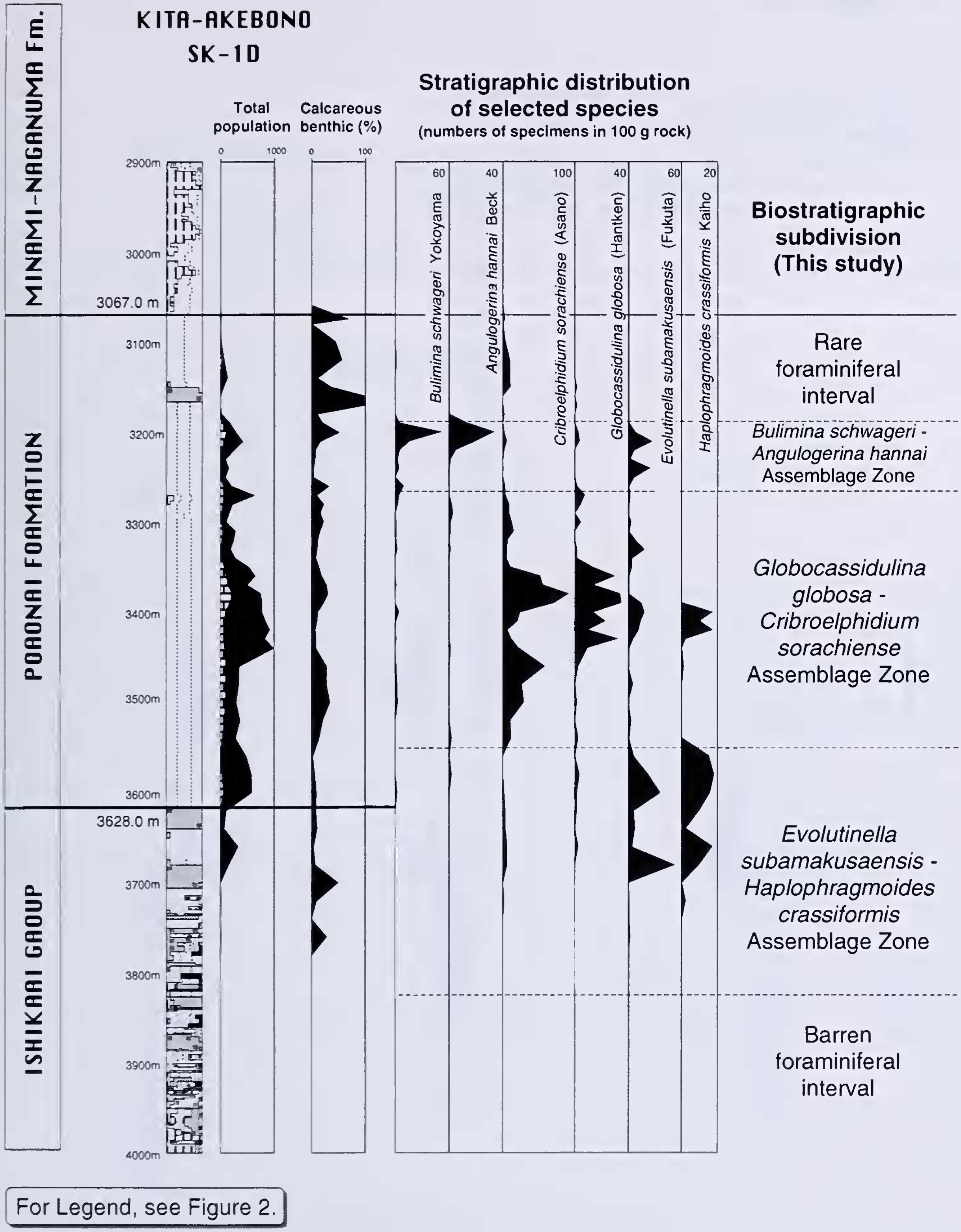


Figure 3. Stratigraphic occurrences of the selected species in Kita-Akebono SK-1D.

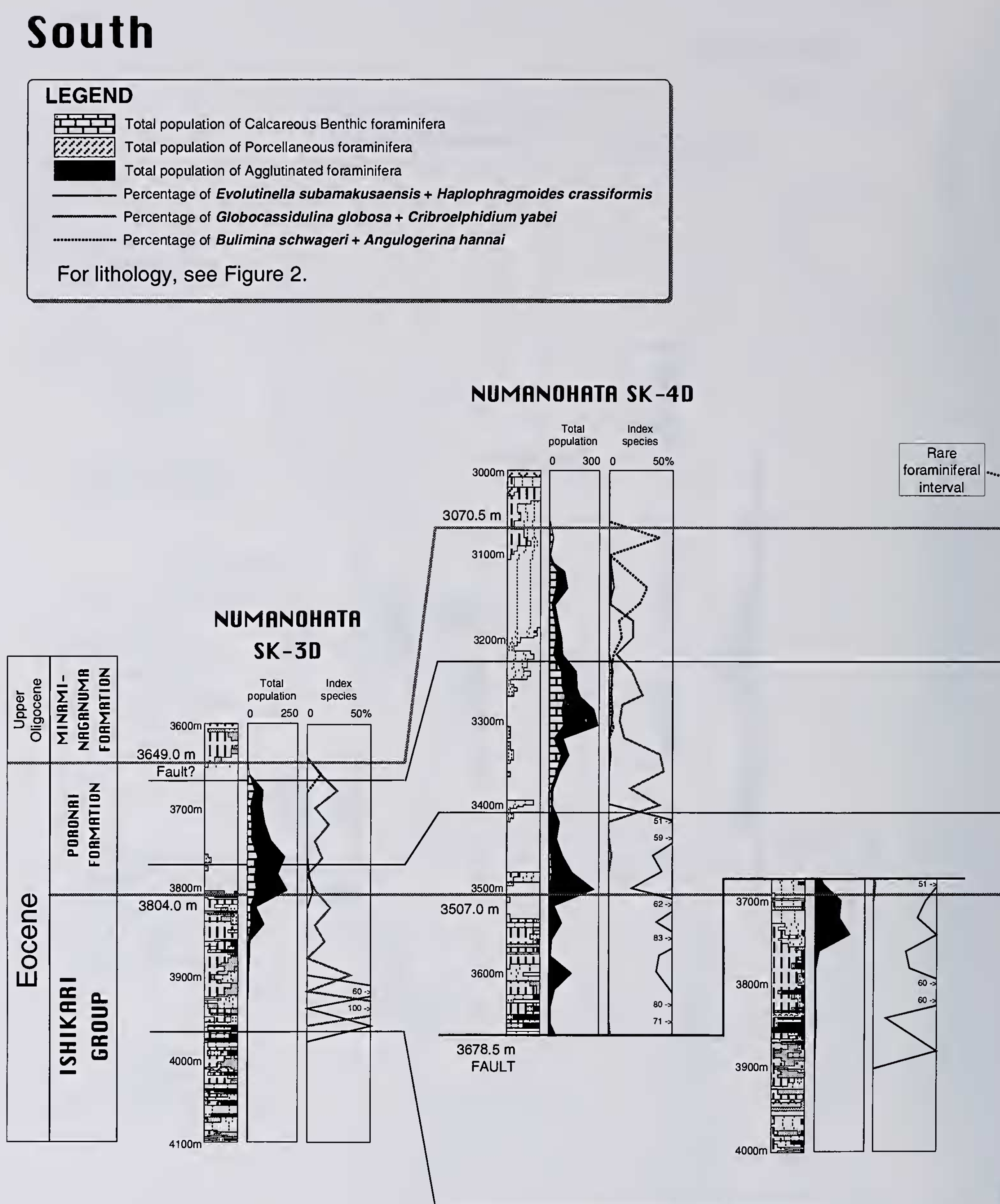
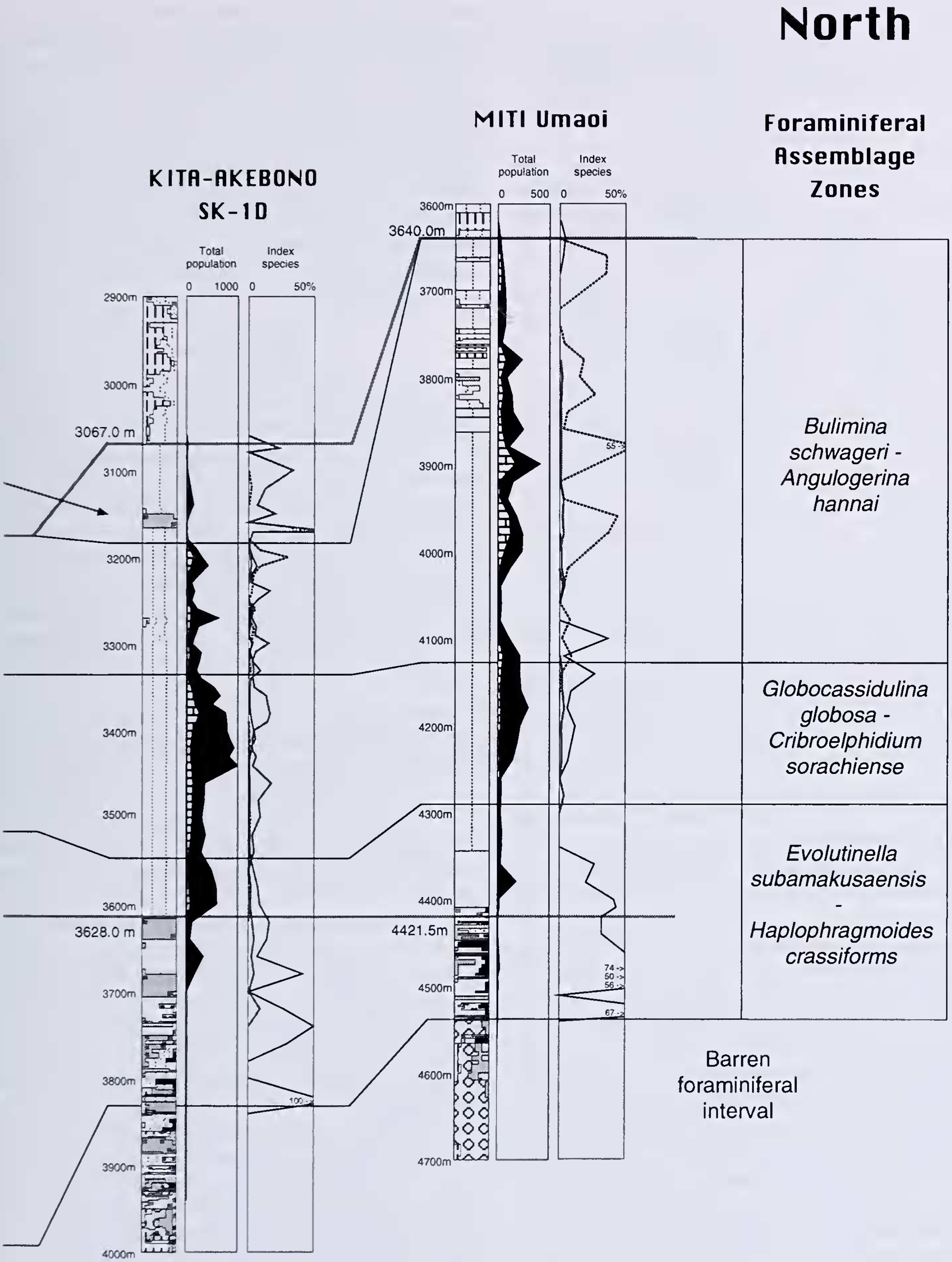


Figure 4. Stratigraphic correlation of the study wells based on the assemblage zones of foraminifera. Left columns of each well section are cumulative (agglutinated, porcellaneous and calcareous foraminifera) total populations in 100 g rock samples. Curves in right column indicate percentage of index species against total population.


North
MITI Umaoi
Foraminiferal Assemblage Zones
KITA-AKEBONO SK-1D
Total population
Index species
0 1000 0 50%
0 500 0 50%
2900m
3000m
3067.0 m
3100m
3200m
3300m
3400m
3500m
3600m
3628.0 m
3700m
3800m
3900m
4000m
3600m
3640.0m
3700m
3800m
3900m
4000m
4100m
4200m
4300m
4400m
4421.5m
4500m
4600m
4700m
Bulimina schwageri - Angulogerina hannai
Globocassidulina globosa - Cribroelphidium sorachiense
Evolutinella subamakusaensis - Haplophragmoides crassiforms
Barren foraminiferal interval

assemblages.

Only populations of specimens identified at species rank were used to calculate diversity; species identified as "spp.", "sp. indet.", and "miscellaneous" were excluded.

Biostratigraphy

As a result of analysis, 47 species belonging to 34 genera were identified from 162 samples (Appendix 1–3). Preservation of most specimens was poor.

The present study established assemblage zones based on associations of index species based on the foraminiferal distribution. Index species are species that are abundant and have similar stratigraphic distribution among all borehole sections.

Occurrences of selected species are plotted against depth for Kita-Akebono SK–1D (Figure 3). This plot reveals that some of the species have distinct similarities in stratigraphic occurrences. On the basis of this, the following three associations are recognized.

1) *Evolutinella subamakusaensis* and *Haplophragmoides crassiformis.*
2) *Globocassidulina globosa* and *Cribroelphidium sorachiense.*
3) *Bulimina schwageri* and *Angulogerina hannai.*

These three associations represent zones which occur in all the studied sections in the same stratigraphic order, and each has a unique distribution within the section (Figure 4). The upper part of the Poronai Formation above the *Bulimina schwageri-Angulogerina hannai* Assemblage Zone in Kita-Akebono SK–1D (depth 3200–3075 m) is referred to here as "rare foraminiferal interval" because the number of foraminifera in the interval is so small. As discussed later, boundaries between these assemblage zones are environmentally controlled and therefore may not indicate strict time horizons.

Characteristics of each assemblage zone are discussed below. Boundaries between the zones are defined by changes in the abundances of the index species.

Evolutinella subamakusaensis-Haplophragmoides crassiformis Assemblage Zone.—This zone is characterized by abundant occurrences of the two index species. It also characteristically includes agglutinated foraminifera such as *Reticulophragmium amakusaensis*, *Cyclammina pacifica*, and *Recurvoidella* sp. cf. *R. lamella.* The calcareous foraminifer *Cribroelphidium sorachiense* occurs rarely in this zone. Assemblages of this zone are characterized by generally small populations and low diversity.

Globocassidulina globosa-Cribroelphidium sorachiense Assemblage Zone.—In addition to the two index species, this zone includes abundant agglutinated foraminifera such as *Evolutinella subamakusaensis*, *Recurvoidella* sp. cf. *R. lamella*, and *Budashevaella symmetrica*, and more calcareous species such as *Melonis pompilioides* and *Pullenia salisburyi* than in the assemblages of the underlying *E. subamakusaensis-H. crassiformis* Assemblage Zone.

Bulimina schwageri-Angulogerina hannai Assemblage Zone.—Although this zone is similar to the *G. globosa-C. sorachiense* Assemblage Zone, it is distinguished by larger numbers and higher frequencies of both *Bulimina schwageri* and *Angulogerina hannai.* Assemblages of this zone also contain numerous agglutinated foraminifera, but have higher calcareous foraminiferal abundances and higher species diversities compared to those of the previous two assemblage zones.

Paleoenvironment

The foraminiferal fauna seen in the present material is characterized by the occurrence of abundant agglutinated foraminifera, especially species belonging to the Lituolidae and Cyclamminidae. No similar fauna so dominated by these agglutinated foraminifera has been reported from anywhere else in the world. Therefore, paleoenvironmental implications of this peculiar fauna are considered based on the facts of modern foraminiferal distribution. In this section, the paleobathymetry of each assemblage zone and then the additional paleoenvironmental implications are discussed.

Paleobathymetry

As discussed by Ingle (1980) and McDougall (1980), paleobathymetric zonations of the Eocene Pacific Ocean are similar to the modern zonations. Paleobathymetric zonations used in the present study follow Akimoto and Hasegawa (1989)'s compilation of bathymetric distributions of Recent benthic foraminifera around the Japanese Islands.

Evolutinella subamakusaensis-Haplophragmoides crassiformis Assemblage Zone.—This zone is considered to have been deposited in a shallow marine environment for the following reasons. First, it overlaps the coal-bearing formation of the Ishikari Group that is of paralic origin. Second, it yields benthic foraminifera *Cribroelphidium sorachiense* and *Sigmoidella pacifica*, both of which suggest shallow marine (sublittoral) deposition. Most modern *Cribroelphidium* live in shallow marine (outer sublittoral zone or shallower) environments, such as *Cribroelphidium bartletti* (*Elphidium bartletti* of Loeblich and Tappan, 1953), *C. clavatum* (*E. clavatum* of Buzas, 1966 and Lagoe, 1979). *Sigmoidella pacifica* also lives in modern shallow marine environments (Jones, 1994, as *S. elegantissima*). Third, assemblages of this zone lack *Globocassidulina* and *Bulimina* whose modern species live at depths greater than the inner sublittoral zone in the seas around the Japanese Islands (Akimoto and Hasegawa, 1989). Thus, the assemblages of the *E. subamakusaensis* — *H. crassiformis* Assemblage Zone are considered to indicate a paleobathymetric range from the littoral zone to the inner sublittoral zone.

Globocassidulina globosa-Cribroelphidium sorachiense Assemblage Zone. —The assemblages of this zone include *Globocassidulina*, which has its upper depth limit in the middle sublittoral zone (Akimoto and Hasegawa, 1989). In addition, *C. sorachiense*, *C. wakkanabense* and *Sigmoidella pacifica*, all of which indicate shallow marine environments, occur frequently in this zone. Therefore, the assemblages of the *G. globosa* — *C. sorachiense* Assemblage Zone are thought to indicate the middle sublittoral zone.

Bulimina schwageri-Angulogerina hannai Assemblage Zone.—The assemblages of this zone are similar to those of the *Globocassidulina globosa-Cribroelphidium sorachiense* Assemblage Zone except that the percentages of *Bulimina* and *Angulogerina* are higher. Since modern species of *Bulimina* and *Angulogerina* have upper depth limits in the outer sublittoral (Akimoto and Hasegawa, 1989), the *Bulimina schwageri-Angulogerina hannai* zone is considered to have been deposited in the outer sublittoral zone. The presence of *Cribroelphidium* species suggests either *in situ* deposition or transport of shallower-water species into the outer sublittoral zone, possible by marine currents.

Kaiho (1992b) reported *B. schwageri* and *A. hannai* in his "intermediate-water" which ranges from depths of 100 to 1000 m. As the depth range of the outer sublittoral zone overlaps the range of Kaiho's "intermediate water," the present study agrees with Kaiho's interpretation on *B. schwageri* and *A. hannai*.

Historical paleobathymetric change.—Paleobathymetric interpretation of the three assemblage zones shows that the sedimentary environments during the deposition of the upper part of the Ishikari Group and the Poronai Formation in the Yufutsu-Umaoi district changed from the littoral zone to the inner sublittoral zone, then to the middle sublittoral zone, and finally to the outer sublittoral zone. The successive change in paleobathymetry suggests that the stratigraphic interval from the first occurrence of foraminifera to the *B. schwageri–A. hannai* Assemblage Zone was deposited during a single transgressive phase. This interpretation supports the observation that the Ishikari Group and the Poronai Formation are conformable in the Yufutsu-Umaoi district.

The "rare foraminiferal interval" at the depth 3190 m and shallower in Kita-Akebono SK–1D well indicates that a regressive phase followed the transgression discussed above. Evidence of the regression is based on the successive disappearances of the species, *B. schwageri*, *A. hannai*, *G. globosa*, and *C. sorachiense*. Shoaling of water depth prevented distribution of these depth-controlled species.

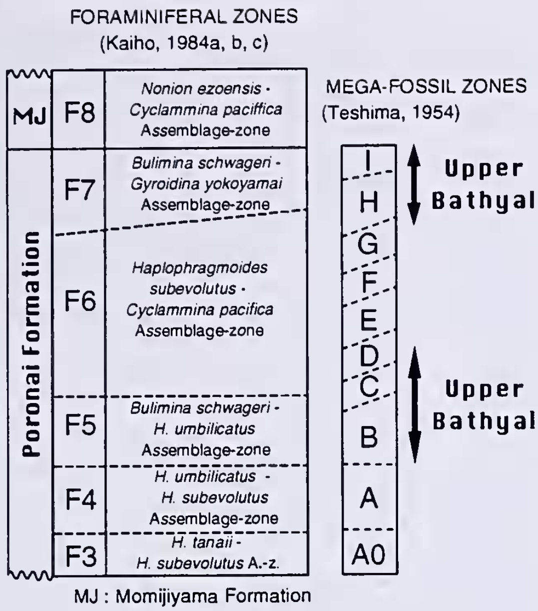


Figure 5. Stratigraphic relation between the megafossil zones and foraminiferal assemblage zones.

Consequently, the interval from the coal-bearing formation of the Ishikari Group to the Poronai Formation in the Yufutsu-Umaoi district accumulated during a single transgressive and regressive sequence. This is only observed in the Kita-Akebono SK–1D well, since the uppermost part of the Poronai Formation is missing in the other well sections.

Upper bathyal assemblages

As a result of the study discussed above, species compositions from the littoral zone to the outer sublittoral zones during the Eocene were described. Foraminiferal fauna of the upper bathyal zone (water depth approximately 180 to 550 m in northwestern Pacific coast of northern Japan), which is one rank deeper than the outer sublittoral zone, is not observed in the Yufutsu-Umaoi district. However, existence of strata which show the upper bathyal environment was reported by Teshima (1955) in the middle part of the Poronai Formation in the Yubari district. Here, I describe upper bathyal foraminiferal fauna based on the correlation between biostratigraphy of Teshima (1955) and Kaiho (1984a, b). Teshima (1955) studied megafossils and divided the Poronai Formation into the A to I megafossil zones in ascending order, stating that the megafossil assemblages of the B-C and H-I zones are similar to the molluscan association found in water depth interval of 200 to 300 m, offshore Otaru, Sea of Japan. This water depth in the Sea of Japan falls within the range of the upper bathyal zone (Akimoto and Hasegawa, 1989). According to the stratigraphic relationship between these megafossil

Species		Sublittoral			Bathyal
		Inner	Middle	Outer	Upper
AGGLUTINATED					
Alveolophragmium	sp.A of the present study		R		
Ammobaculites	sp. A of Kaiho, 1984b			A	
Ammobaculkites	*akabiraensis* Asano	R	R	R	
Ammodiscus	*parianus* Hedberg		R	C	R
Ammodiscus	*tenuis* Brady		R	C	C
Ammomarginulina	sp. A of Keiho, 1984b			R	
Bathysiphon	*eocenica* Cushman and Hanna	R	R	C	C
Bathysiphon	*vemoni* Hamlln	R	R	R	C
Budashevaella	sp. aff. *B. multicamerata* (Voloshinove)			R	
Budashevaella	*symmetrica* (Ujiie and Wetanabe)	R	C	C	R
Cribrostomoides	sp. cf. *C. cretacea* Cushman and Goudkoff		R	R	?
Cyclammina	*ezoensis* Asano	R	R	R	R
Cyclammina	*orbicularis* Brady			R	
Cyclammina	*pacifica* Beck	R	C	A	A
Cyclammina	sp. aff. *C. pusilla* Brady	R	R	R	R
Cyclammine	*tani* Ishizaki				R
Cyclammina	sp. A of the present sludy			R	
Cyclammina	sp. B of the presenl sludy	R			
Discammina	sp. A of Kaiho, 1984b	R	R	C	R
Discammina	sp. B of Kaiho, 1984b		?	R	R
Discammina	sp. C of Kaiho, 1984b	R	R	R	
Eggerella	sp. A of Kaiho, 1984b			R	
Evolutinella	*subamakusaensis* (Fukuta)	**A**	C	R	R
Glomospira	*gordialis* Jones and Parker			R	
Haplophragmoides	*crassiformis* Kaiho	**C**	C	R	R
Haplophragmoides	sp. cf. *H. deflata* Sullivan				R
Haplophragmoides	*rugosus soyaensis* Yasuda		**C**	C	R
Haplophragmoides	*tanaii* Kaiho		**C**	C	
Haplophragmoides	*yokoyamai* Kaiho		R	R	R
Haplophragmoides	sp. A of the present study			R	?
Haplophragmoides	sp. B of the present study	R	R	R	?
Haplophragmoides	sp. D of the present study	C	R	R	?
Hyperammina	*elongata* Brady			R	R
Karrerulina	sp. cf. *K. hokkaidoana* (Takayanagi)			**C**	R
Martinottiella	*crassa* Kaiho			R	
Martinottiella	*rectidelicata* Kaiho				R
Placentammina	sp. A of the present study		R	R	?
Poronaia	*poronaiensis* (Asano)	**C**	R	C	R
Recurvoidella	sp. cf. *R. lamella* (Grzybowski)	A	C	C	?
Recurvoides	sp. A of the present study			R	?
Reophax	*minutirectus* Kaiho				R
Reophax	*multicamerarus* Kaiho			R	C
Reophax	*tappuensis* Asano	**C**	C	C	C
Reticulophragmium	*amakusaensis* (Fukuta)	**C**	C	A	?
Rhabdammina	sp.			R	R
Silicosigmoilina?	sp.				R
Spiroplectammina	*nuttalii* Lalicker				R
Trochammina	sp. cf. *T. asagaiensis* Asano		C	C	
Trochammina	*squamata* Jones and Parker			C	R
Verneuilinula	*takayanagii* (Kaiho)			R	R
PORCELLANEOUS					
Quinqueloculina	*seminula compacta* Serova	R	C	C	R
Triloculina	*gibba* d'Orbigny	R	R	R	R
CALCAREOUS HYALINE					
Anomalinoides	*sasai* Kaiho			R	C
Anomalinoides	sp. A of Kaiho, 1984b				R
Bolivina	*euplectella* Yokoyama				R
Brizarina	*saitoi* Kaiho			R	C
Brizarina	*serrata* Kaiho			R	C
Bulimina	*schwageri* Yokoyama			**A**	A
Bulimina	*sculptilus* Cushman				C
Bulimina	sp. cf. *B. sculptilus* Cushman			R	C
Bulimina	*yabei* Asano and Murata			**C**	R
Buliminella	*robertsi* Howe and Ellis			**C**	
Cancris	*torquertus* Cushman and Todd				R
Cassidulina	*lobatula* Kaiho				R
Cassidulina	*yubariensis* Kaiho			R	R
Cassidulinoides	*howei* Cushman				**C**
Chilostomella	sp. cf. *C. cylindoroides* Reuss				R
Cibicides	*elmaensis* Rau		R	R	R
Cibicides	*complanatus* Kaiho			R	
Cibicides	sp. A of Kaiho, 1984b			R	
Cibicides	sp. B of Kaiho, 1984b				R
Cribroelphidium	*ishikariense* (Kaiho)	R	R	R	R
Cribroelphidium	*sorachiense* (Asano)	R	A	A	C
Cribroelphidium	*sorachiense* (Asano) var. A			R	
Cribroelphidium	*wakkanabense* (Kaiho)	R	C	A	
Dentalina	sp. cf. *D. kushiroensis* Yoshida			R	
Dentaline	sp. cf. *D. subsoluta* (Cushman)			R	C
Dentalina	*cocoaensis* (Cushman)			R	C
Dentalina	*dusenburyi* Beck			R	C
Dentalina	*minuta* Kaiho				R
Elphidium	*mabutii* Asano*	?	?	R	?
Elphidium	sp. A of Kaiho, 1984b		R		
Epistominella	*exigua multiloculate* Kaiho				**C**
Eponides	*lobatus* Kaiho			R	C
Fissurina	*marginata* (Montagu)		R	R	C
Fissurina	sp. A of Kaiho, 1984b			R	R
Fursenkoina	*uchioi* Kaiho			R	C
Glandulina	*laevigata ovata* Cushman and Applin		C	C	C
Globobulimina	*ezoensis* (Yokoyama)			C	C
Globocassidulina	*globosa* (Hantken)		A	C	C
Globocassidulina	sp. A of Kaiho, 1984b			R	C
Globulina	*gibba* (d'Orbigny)			R	C
Guttulina	*problema* (d'Orbigny)	**C**	C	C	C
Guttulina	*takayanagii* Kaiho	R	R	R	R
Gyroidina	*yokoyamai* (Ujiie and Watanabe)				**A**
Heterolepa	*poronaiensis* Kaiho	R	R	C	
Lagena	sp. cf. *L. laevis* (Montagu)	R	R	R	R
Lagena	sp. cf. *L. perlucida* (Montagu)				C
Lagene	sp. cf. *L. sulcata* (walter and Jacob)			R	
Lagena	*striata* (d'Orbigny)			R	R
Lagena	sp. A of Kaiho, 1984b				R
Lenticuline	*antipode* (Stache)				**C**
Lenticulina	*ishikariensis* Kaiho				**C**
Lenticulina	sp. A of Kaiho, 1984b			R	R
Lenticulina	sp. B of Kaiho, 1984b				R
Melonis	*affinis* (Reuss)		R	R	R
Melonis	*elegans* Kaiho			R	C
Melonis	*lobatus* Kaiho				R
Melonis	sp. cf. *M. multisuturalis* van Bellen				R
Melonis	*pompilioides* (Fitchel and Moll)	R	C	C	C
Melonis	*subevolutus* Kaiho			R	R
Nodogeneria	sp. cf. *N. lepidula* (Schwager)			R	C
Nodosaria	*amchitkaensis* (Todd)**				C
Nodosaria	*longiscata* d'Orbigny			R	C
Nonion	*ezoensis* Kaiho			R	C
Nonion	*subangularis* Kaiho			R	R
Nonion	*takayanagii* Kaiho			R	
Nonionella	*jeponica* (Yokoyama)			R	R
Nonionella	*mabutii* Asano				R
Oolina	*hexagona* (Williamson)				C
Oolina	*simplex* Reuss			R	C
Oolina	sp. cf. *O. globosa* (Montagu)			R	R
Oolina	sp. A of Kaiho, 1984b				R
Planulina	*poronaiensis* Asano	R			
Plectofrondicularia	*delicatula* Kaiho				R
Plectofrondicularia	*packardii* Cushman and Schencki				**C**
Plectofrondicularia	*smithi* Kaiho				**C**
Plectofrondicularia	*vaughani* Cushman				R
Praeglobobulimina	*pyrula* (d'Orbigny)		R	R	R
Praeglobobulimina	*ovata* (d'Orbigny)			R	R
Praeglobobulimina	*pupoides* (d'Orbigny)				C
Procerolagena	sp. cf. *P. gracillima* (Sequenza)			R	R
Pseudonodosaria	*conica* (Neugeboren)	R	R	R	
Pseudonodosaria	*inflata* (Costa)	R	R	R	C
Pseudopolymorphina	*hokkaidoana* Kaiho	R	R	R	R
Pullenia	*eocenica* Cushman and Siegfus	R	R	C	?
Pullenia	*salisburyi* R. E. and K. C. Stewart		**C**	C	C
Saraceneria	*ujiiei* Kaiho			R	R
Sigmoidella	*pacifica* Cushman and Ozawa	**C**	C	C	C
Sigmomorphina	*schencki* Cushman and Ozawa			C	C
Sigmomorphina	sp. A of Kaiho, 1984b				R
Stilostomella	sp. cf. *S. japonica* (Ishiwada)				R
Trifarina	*hannai* (Beck)			**C**	C
Uvigerina	*ombetsuensis* Kaiho				R
Valvulineria	*lymani* (Yokoyama)			R	R

Figure 6. Paleobathymetric distribution of benthic foraminifera. Data of Asano (1952), Ujiié and Watanabe (1960) and Kaiho (1984a, b) are also interpreted by the present study. R = Rare; C = Common; A = Abundant. Occurrences of species shown in boldface are supposed to be important for paleobathymetric interpretations. Occurrences of species with * are restricted in the Utsunai Formation (Kaiho, 1984b), and with ** to the Omagari Formation (Asano, 1952; Kaiho, 1984b).

zones (B-C and H-I) and foraminiferal assemblage zones indicated by Kaiho (1984a; Figure 5), it is obvious that foraminiferal assemblage zones F5 and F7 (Kaiho, 1984a, c) were deposited in the upper bathyal zone. The foraminiferal assemblages of these zones contain abundant *Bulimina schwageri* and *Angulogerina hannai* (Kaiho, 1984a, c) as well as numerous calcareous foraminifera such as *Gyroidina yokoyamai* and *Plectofrondicularia packardii.* These latter two species were not encountered in the Yufutsu-Umaoi district and therefore must represent the

Eocene upper bathyal zone.

Paleobathymetric distributions of benthic foraminifera in the Poronai Sea are summarized in Figure 6 based on the present study and compilation of previous reports (Asano, 1952; Ujiié and Watanabe, 1960; Kaiho, 1984a, b).

Paleoenvironmental implications of abundant agglutinated foraminifera

The paleobathymetric distributions of benthic foraminifera in the study area indicate that the shallower marine assemblages include higher abundances of agglutinated foraminifera. Because similar assemblages dominated by agglutinated foraminifera have not been reported from other coastal regions of the North Pacific while various calcareous species have been reported (e.g. Ingle, 1980; McDougall, 1980), a local environmental factor is considered to have controlled the distribution.

Greiner (1970) proposed that availability of calcium carbonate for test construction is the controlling environmental factor in the distribution of calcareous foraminifera. In environments where calcium carbonate availability is insufficient for calcareous foraminifera, agglutinated foraminifera dominate. Examples of environments with insufficient calcium carbonate are found in brackish coastal areas, estuaries, and marshes (e.g., Zalesny, 1959; Bandy and Arnal, 1960; Anderson, 1963; Scott *et al.*, 1983; Zheng and Fu, 1992). Highly diverse agglutinated foraminiferal associations are also reported from the Arctic Ocean, in areas affected by the brackish surface water (Vilks, 1969; Hunt and Corliss, 1993; Schröder-Adams *et al.*, 1990).

Based on these modern examples of foraminiferal ecology, abundant occurrences of agglutinated foraminifera from the Ishikari Group and the Poronai Formation are thought to be the result of deposition in areas under the influence of brackish surface-water.

Water stratification

Previous studies on the lithostratigraphy and dinoflagellate assemblages showed that water stratification was important in the basal part of the Poronai Formation (Matsuno *et al.*, 1964; Kurita and Matsuoka, 1994). Previous studies also supposed that the Poronai Formation was deposited in an embayment called the "Poronai Sea" (Teshima, 1967; = "Paleo-Poronai Sea" of Kaiho, 1983, 1984c). This interpretation is mainly based on the geographical distribution of the Poronai Formation and its equivalents (Figure 1A). Absence or rare occurrences of planktonic foraminifera and radiolarians in the Yufutsu-Umaoi district indirectly support this interpretation. Such closed paleogeography may be an important factor for the water stratification.

According to Kaiho (1984a, b), Teshima (1955)'s megafossil zone A, found in the basal part of the Poronai Formation, corresponds approximately to the foraminiferal zones from the *Haplophragmoides tanaii-Haplophragmoides subevolutus* Assemblage Zone to the *Haplophragmoides umbilicatus-H. subevolutus* Assemblage Zone of Kaiho (1984a, c; Figure 5). Accounting for the synonymies discussed in the taxonomic section below, species composition of Kaiho's zones is similar to the *Evolutinella subamakusaensis-Haplophragmoides crassiformis* Assemblage Zone and the *Globocassidulina globosa-Cribroelphidium sorachiense* Assemblage Zone of the Yufutsu-Umaoi district. This similarity shows that the stratigraphic interval from the *H. tanaii-H. subevolutus* Assemblage Zone to the *H. umbilicatus-H. subevolutus* Assemblage Zone in the Yubari district was deposited under paleobathymetric conditions within, or shallower than, the middle sublittoral zone of the Yufutsu-Umaoi district.

Matsuno *et al.* (1964) also pointed out that the megafossil zone A defined by Teshima (1955), at the basal part of the Poronai Formation in the Yubari coal field, is rich in organic carbon and presumably was deposited in an oxygen-depleted paleoenvironment.

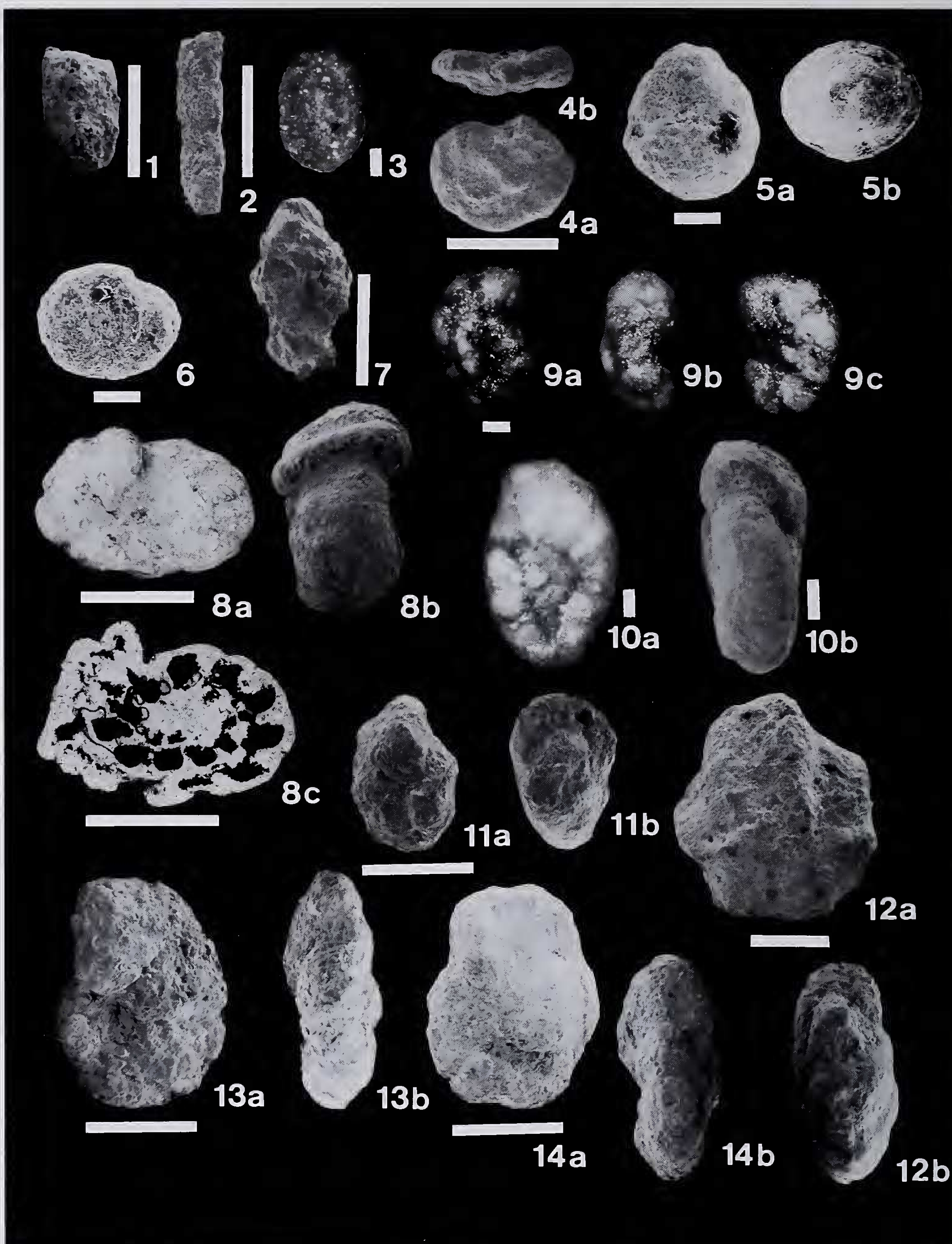
Based on these lines of evidence, sediments deposited in stratified shallow marine water masses are widely distributed in the Poronai Formation of the Yufutsu-Umaoi district and the Yubari district. These stratified water masses are believed to have formed as a result of fresh water input, as suggested by the dominant agglutinated foraminifers. In such an environment, a decreasing supply of dissolved oxygen from the sea surface may have caused oxygen depletion in substratum due to degradation of organic matter, as commonly observed in modern shallow marine areas (Tyson and Pearson, 1991).

Conclusion

Three Eocene foraminiferal assemblage zones, *Evolutinella subamakusaensis-Haplophragmoides crassiformis* Assemblage Zone, *Globocassidulina globosa-Cribroelphidium sorachiense* Assemblage Zone and *Bulimina schwageri-Angulogerina hannai* Assemblage Zone, in ascending order, were defined in the well sections of the Yufutsu-Umaoi district, southern central Hokkaido. Assemblages characterizing each assemblage zone indicate the littoral to inner sublittoral zone, the middle sublittoral zone and the outer sublittoral zone, respectively.

Furthermore, compositions of foraminiferal assemblages of the Eocene upper bathyal zone were described based on a reevaluation of the previous studies. The upper bathyal zone is characterized by occurrence of abundant calcareous species such as *Gyroidina yokoyamai* and *Plectofrondicularia packardii*.

Abundant occurrences of agglutinated foraminifera suggest brackish-water paleoenvironments caused by fresh-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11b
12a
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13b
14a
14b
12b

water input. Such brackish water may cause stratification and resultant oxygen depletion.

As a result of the present study, compositions of Eocene shallow marine foraminiferal assemblages in northern Japan were revealed. These data are expected to form a basis for considering the geohistory of the Paleogene formations in Hokkaido, as well as the paleoceanography of the northwestern Pacific region during the Eocene.

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Taxonomic notes

Species which occurred in the Yufutsu-Umaoi district are arranged in taxonomic order following Loeblich and Tappan (1987). For the present identification, topotype, ideotype and hypotype specimens collected by K. Kaiho and presently deposited in JAPEX Research Center, Chiba, Japan, were compared. Because of poor preservation of the specimens, no new species were described herein, although several synonymies are discussed. All figured specimens are deposited in the collection of JAPEX Research Center.

Bathysiphon eocenica Cushman and Hanna (Figure 7.1)

Bathysiphon eocenica Cushman and Hanna, 1927, p. 210. pl. 13, figs. 2, 3. —Asano, 1952, p. 31, pl. 3, figs. 3, 4. —Ujiié and Watanabe, 1960, p. 127, pl. 1, figs. 3, 4. —Fukuta, 1962, p.7, pl. 1, fig. 1. —Kaiho, 1984b, p. 42, pl. 1, figs. 3a, b. —Kaiho, 1992b, p. 365, pl. 1, fig. 1, pl. 5, fig. 1, 2.

Bathysiphon vernoni Hamlin (Figure 7.2)

Bathysiphon vernoni Hamlin, 1963, p. 153, pl. 14, figs. 1a–2b. —Kaiho, 1984b, p. 42, pl. 1, fig. 4.

Placentammina sp. A (Figure 7.5, 7.6)

Description.—Test free, small, unilocular, pyriform; very finely agglutinated and almost transparent; aperture round opening at the top of pyriform shell with very short projection.

Remarks.—Almost all of the specimens were deformed secondarily.

Reophax tappuensis Asano (Figure 7.7)

Reophax tappuensis Asano, 1958, p. 71, pl. 13, figs. 8, 9. —Kaiho, 1984b, pl. 1, figs. 10a–12.

Cribrostomoides* sp.** cf. ***C. cretacea Cushman and Goudkoff (Figure 7.11, 7.12)

Cf. *Cribrostomoides cretacea* Cushman and Goudkoff, 1944, p. 54, pl. 9, figs. 4a, b.

Remarks.—All specimens are so distorted that accurate identification is difficult. Coiling planes are always tilted to show very weak streptospiral involute coiling, therefore this form must be assigned to genus *Cribrostomoides* following Jones *et al.* (1993). It is distinguishable from allied species in its involute coiling, six to eight inflated chambers in final whorl, finely agglutinated and slightly transparent wall.

Evolutinella subamakusaensis (Fukuta) (Figure 8.10–8.12)

Cribrostomoides cf. *cretacea* Cushman and Goudkoff. —Ujiié and Watanabe, 1960, p. 127, pl. 1, figs. 3–5.

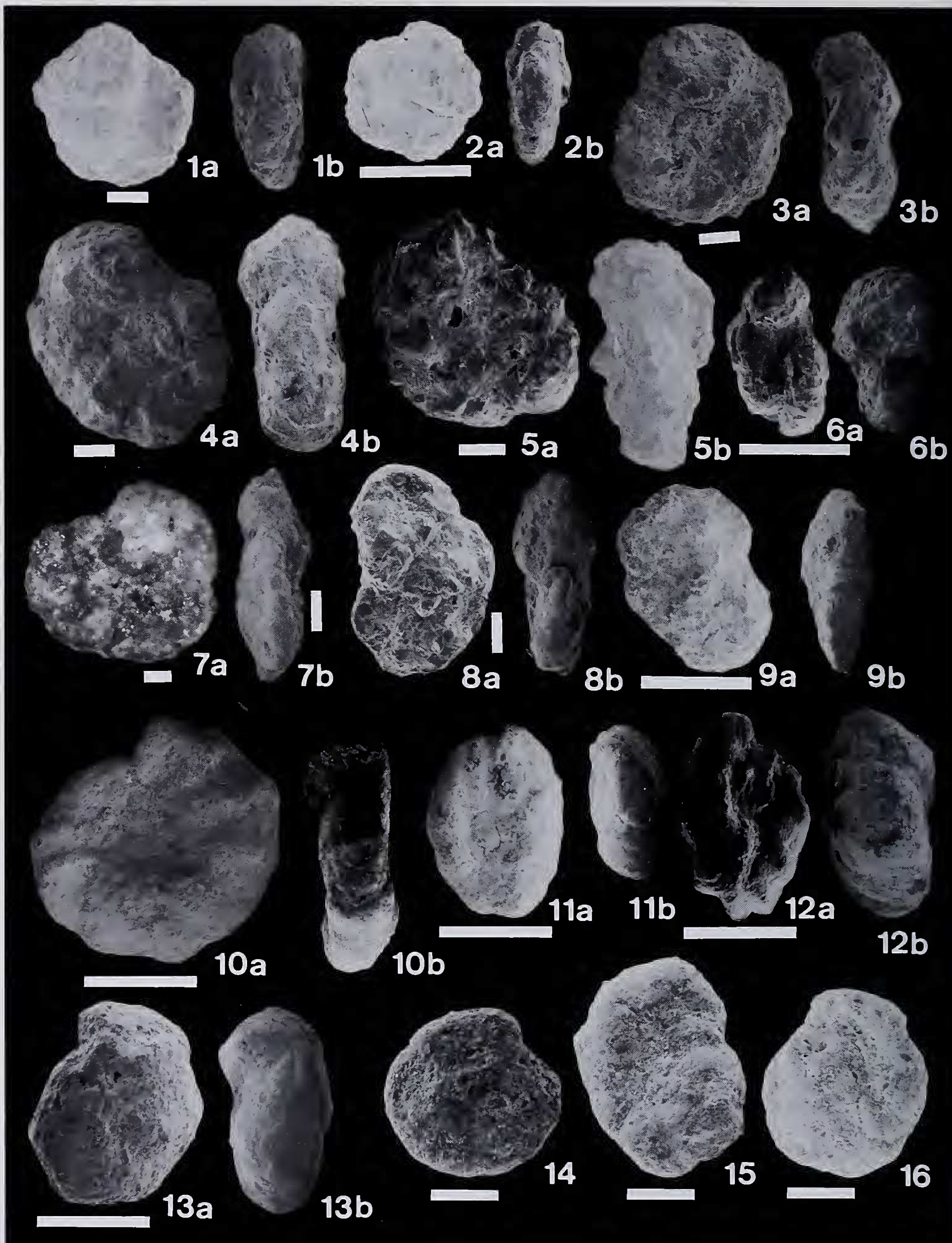
Haplophragmoides subamakusaensis Fukuta, 1962, p. 9, fig. 2, pl. 1, figs. 6–10.

Haplophragmoides subevolutus Kaiho, 1984a, p.114, pl. 7, figs. 7a, b. —Kaiho, 1992c, pl. I, figs. 8a, b.

Cribrostomoides sp. A. Yasuda, 1986, p. 51, pl. 3, figs. 9a, b.

Description.—Test free, planispirally enrolled, frequently coiling plane is unstable and sometimes show streptospiral appearance, slightly to completely evolute;

← **Figure 7.** Foraminifera from the Poronai Formation and Ishikari Group appearing in the wells studied. Scale bars equal 100 μm except figs. 1, 2, 4, 7, 8, 11, 12, 13, and 14, where bars equal 500 μm. **1.** *Bathysiphon eocenica* Cushman and Hanna, from MITI Umaoi, 3840 m. **2.** *Bathysiphon vernoni* Hamlin, from Kita-Akebono SK-1D, 3580 m. **3.** *Ammodiscus* sp., from Numanohata SK-4D, 3600 m. **4a, b.** *Glomospira* sp., from Numanohata SK-4D, 3305 m. **5a, b.** *Placentammina* sp. A, from Kita-Akebono SK-1D, 3330 m. **6.** *Placentammina* sp. A, from Kita-Akebono SK-1D, 3310 m. **7.** *Reophax tappuensis* Asano, from Kita-Akebono SK-1D, 3320 m. **8a–c.** *Budashevaella* sp. aff. *B. multicamerata* (Voloshinova), from MITI Umaoi, 4000 m. **9a–c.** *Budashevaella symmetrica* (Ujiié and Watanabe), from Numanohata SK-4D, 3240 m. **10a, b.** *Budashevaella symmetrica* (Ujiié and Watanabe), from MITI Umaoi, 3720 m. **11a, b.** *Cribrostomoides* sp. cf. *C. cretacea* Cushman and Goudkoff, from Numanohata SK-4D, 3340 m. **12a, b.** *Cribrostomoides* sp. cf. *C. cretacea* Cushman and Goudkoff, from Kita-Akebono SK-1D, 3250 m. **13a, b.** *Haplophragmoides crassiformis* Kaiho, from Numanohata SK-4D, 3660 m. Specimen bilaterally compressed by secondary deformation. **14a, b.** *Haplophragmoides crassiformis* Kaiho, from Kita-Akebono SK-1D, 3640 m.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biumbilicate; chambers inflated, 7–12 in final whorl; wall thin, finely agglutinated, exterior smoothly finished; aperture interiomarginal.

Remarks. — This species is assigned to the genus *Evolutinella* because of its evolute planispiral coiling. It is also characterized by numerous chambers and finely agglutinated wall. Ujiié and Watanabe (1960) first reported this species from the Poronai Formation as *Cribrostomoides* cf. *cretacea* Cushman and Goudkoff. Subsequently, Fukuta (1962) included the form in the synonymy of his *Haplophragmoides subamakusaensis* described from the Kyoragi Formation of the Amakusa Islands, Kyushu, and noted that this species was found also from the Poronai, Akabira and Wakkanabe Formations of the Ishikari Coal field. Later, Kaiho (1984a) described *H. subevolutus* from the Poronai Formation and synonymized *C.* cf. *cretacea* of Ujiié and Watanabe (1960) without reference to the study of Fukuta (1962). *H. subamakusaensis* and *H. subevolutus* have quite similar morphology and are regarded here as synonyms. Kaiho and Nishi (1989) reported *H. subevolutus* from the Middle Eocene to Early Oligocene Hyuga Group in southern Kyushu without any figures. Thus it is obvious that *E. subamakusaensis* has a broad geographic distribution from Hokkaido to Kyushu, and a long stratigraphic range from the Maastrichtian to lower Oligocene. Kaiho (1984a) included the specimens having numerous chambers, up to 14, in the final whorl in *H. subevolutus.* However, I did not find specimens having more than 13 chambers in the present study. In Figures 8–12, specimens collected from the Kyoragi Formation (not topotypes but collected from near the type locality) are shown for comparison.

Haplophragmoides crassiformis Kaiho (Figure 7.13, 7.14)

Haplophragmoides cf. *emaciata* (Brady). —Ujiié and Watanabe, 1960, p. 127, pl. 1, figs. 6a, b.

Haplophragmoides crassiformis Kaiho, 1984a, p. 114, pl. 7, figs. 3a, b.

Haplophragmoides rugosus soyaensis Yasuda (Figure 8.3, 8.4)

Haplophragmoides rugosus soyaensis Yasuda, 1986, p. 50, pl. 5, figs. 5a–7c.

Haplophragmoides umbilicatus Kaiho, 1984a, p. 115, pl. 7, figs. 6a, b. (non *Haplophragmoides umbilicatus* Pearcey).

Haplophragmoides apertiumbilicatus Kaiho, 1986, nom. nov.

Remarks.—This species is characterized by its deeply depressed umbilicus, seven inflated chambers in the final whorl, and compact arrangement of chambers. Distinguished from *H. amakusaensis* Asano in possessing curved sutures.

Haplophragmoides tanaii Kaiho (Figure 8.5)

Haplophragmoides tanaii Kaiho, 1984a, p. 115, pl. 7, figs. 5a, b.

Remarks.—This species is characterized by its small test size, coarsely agglutinated wall, and subacute periphery. *H. kushiroensis* Asano (1962) described from the Paleogene of eastern Hokkaido has similar morphology in its test size, number of chambers, acute periphery and coarsely agglutinated wall but is supposed to be distinguished by possessing curved sutures.

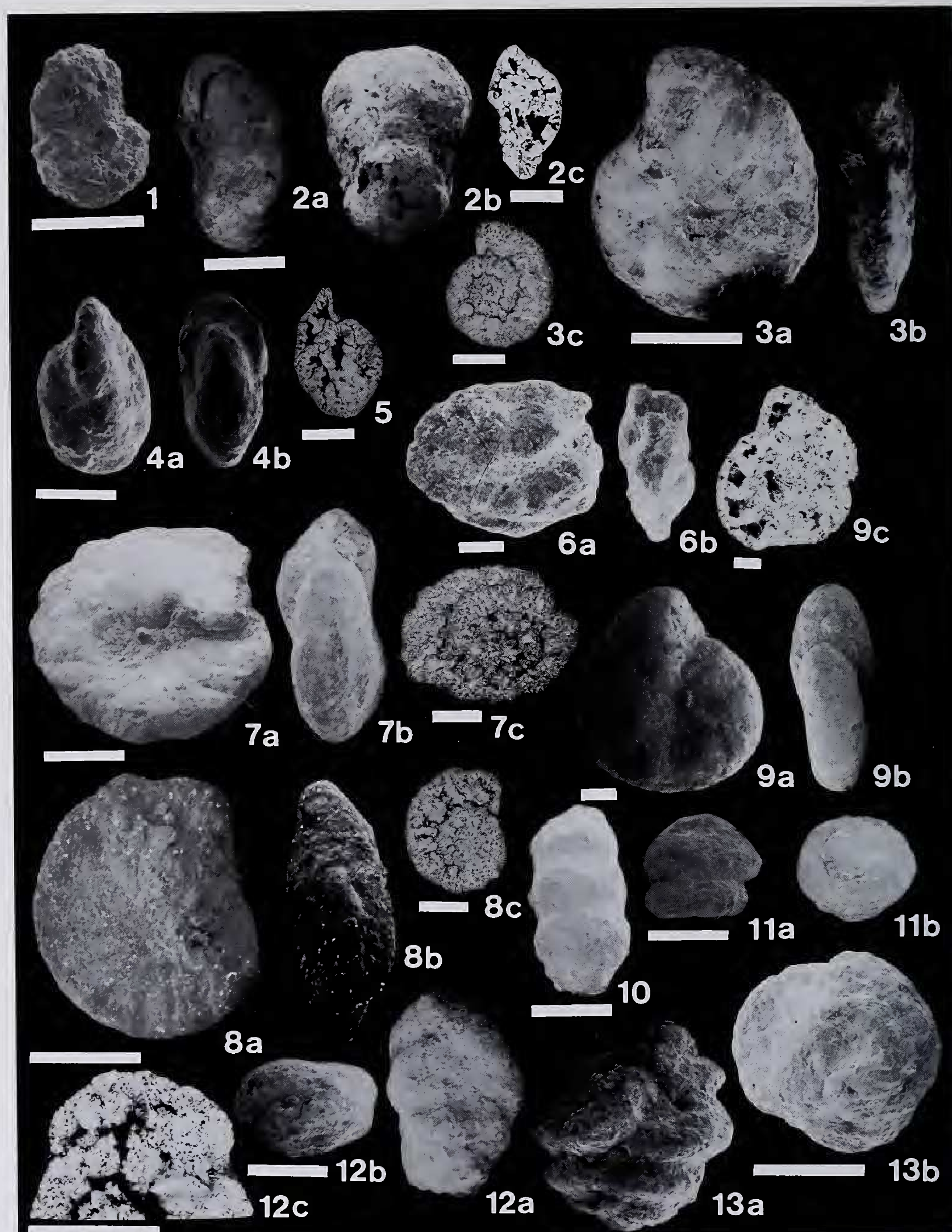
Haplophragmoides yokoyamai Kaiho (Figure 8.1, 8.2)

Haplophragmoides kirki Wickenden; Mallory, 1959, p. 112, pl. 2, figs. 8a, b. —Takayanagi, 1960, p. 72, pl. 2, figs. 3a, b.

Haplophragmoides yokoyamai Kaiho, 1984a, p.116, pl. 7, figs. 4a, b.

Remarks.—Mallory (1959) first reported this species as *H. kirki* from the Eocene of California. Takayanagi (1960) also reported this species from the Albian to Campanian of Hokkaido as *H. kirki.* Later Kaiho (1984a) described *H. yokoyamai* from the Poronai Formation as new. The holotype of *H. kirki* from the Cretaceous of North America (Wickenden, 1932, p.85, pl. 1, fig. 1) shows a smaller test, broadly rounded periphery and more finely agglutinated wall compared to *H. yokoyamai.* Furthermore, specimens of Mallory (1959) and Takayanagi (1960) have a compressed test, larger test size and a coarser wall than typical *H. kirki.* Moreover, *H. kirki* is synonymized to *H. excavata* Cushman and Walters by Mello (1971), who added that *H. excavatus* shows such a wide range of morphological variation that *H. kirki* falls within the range of variation of the

← **Figure 8.** Foraminifera from the Poronai Formation and Ishikari Group appearing in the wells studied. Specimens shown for comparison in Figure 12a, b were collected from the Kyoragi Formation. Scale bars equal 100 μm except figs. 2, 6, 9, 10, 11, 12, and 13, where bars equal 500 μm. **1a, b.** *Haplophragmoides yokoyamai* Kaiho, from MITI Umaoi, 3840m. Medium-sized specimen. **2a, b.** *Haplophragmoides yokoyamai* Kaiho, from MITI Umaoi, 3840 m. Largest-size specimen. **3a, b.** *Haplophragmoides rugosus soyaensis* Yasuda, from MITI Umaoi, 4160 m. **4a, b.** *Haplophragmoides rugosus soyaensis* Yasuda, from MITI Umaoi, 4160 m. **5a, b.** *Haplophragmoides tanaii* Kaiho, from MITI Umaoi, 4000 m. **6a, b.** *Haplophragmoides* sp. A, from Numanohata SK-4D, 3110 m. **7a, b.** *Haplophragmoides* sp. B, from MITI Umaoi, 4060 m. **8a, b.** *Haplophragmoides* sp. B, from Kita-Akebono SK-1D, 3350 m. **9a, b.** *Haplophragmoides* sp. D, from MITI Umaoi, 3820 m. **10a, b.** *Evolutinella subamakusaensis* (Fukuta), from Numanohata SK-4D, 3600 m. Specimen bilaterally compressed by secondary deformation. **11a, b.** *Evolutinella subamakusaensis* (Fukuta), from Numanohata SK-4D, 3600 m. Specimen vertically compressed by secondary deformation. **12a, b.** *Evolutinella subamakusaensis* (Fukuta), from the Kyoragi Formation. Specimen vertically compressed by secondary deformation. **13a, b.** *Recurvoides* sp. A, from MITI Umaoi, 3920 m. **14-16.** *Recurvoidella* sp. cf. *R. lamella* (Grzybowski), all specimens from Numanohata SK-4D, 3500 m.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12a
12b
12c
13a
13b

former species.

Recurvoidella sp. cf. ***R. lamella*** (Grzybowski) (Figure 8.14–8.16)

Cf. *Trochammina lamella* Grzybowski, 1898, p. 290, pl. 11, fig. 25.

Cf. *Recurvoidella lamella* (Grzybowski). —Charnock and Jones, 1990, p. 173, pl. 6, figs. 11, 12, pl. 17, fig. 7; Kaminski and Geroch, 1993, p. 263–264, pl. 10, figs. 8, 9.

Remarks.—Most specimens are depressed almost completely.

Budashevaella symmetrica (Ujiié and Watanabe) (Figure 7.9, 7.10)

Trochammina symmetrica Ujiié and Watanabe, 1960, p. 134, pl. 1, figs. 10, 11.

Description.—Test free, medium, early stage compactly streptospiral; the angle between one coiling plane and subsequent one increases as growth proceeds, up to 90° in an adult form, the last whorl and half of the penultimate whorl are visible on the surface in a juvenile form, but the penultimate one becomes almost invisible in the adult, few chambers of penultimate whorl exposed in umbilical area; slightly evolute; chambers not inflated in earlier coil, become slightly inflated, seven to eight in final whorl, increasing slowly in size as added; sutures radial, slightly depressed, limbate; wall finely agglutinated, thick; aperture interiomarginal.

Remarks.—The streptospiral coiling of this species confirms the assignment to the genus *Budashevaella*. This species is similar to *Haplophragmoides subamakusaensis* Fukuta in general appearance but is distinguished by its less inflated chambers, less depressed sutures and streptospiral coiling. It is also distinguished from *Budashevaella* sp. aff. *B. multicamerata* of the present study in having fewer number of chambers in the final whorl.

Budashevaella **sp.** aff. ***B. multicamerata*** (Voloshinova) (Figure 7.8)

Aff. *Circus multicameratus* Voloshinova, in Voloshinova and Budasheva, 1961, p. 201, pl. 7, fig. 6, pl. 8, fig. 1.

Budashevaella multicamerata (Voloshinova). — McDougall, 1980, p. 34, pl.3, figs. 4–6.

Diagnosis. — Numerous chambers up to 14 in final whorl. Coiling plane of the last coil lies at about a right angle to that of the penultimate one in the umbilical area.

Remarks. — This form is distinguished from *B. multicamerata* (Voloshinova), originally described as *Circus multicameratus* from the Neogene of Sakhalin, in its broadly rounded periphery.

Reticulophragmium amakusaensis (Fukuta) (Figure 9.9)

Cyclammina amakusaensis Fukuta, 1962, p.12, text-figs, 3a–b, pl. 3, figs. 8–10.

Description. — Test free, medium, planispirally coiled and involute to very slightly evolute, 10–13 chambers in final whorl, whorls increasing rapidly in height; wall finely agglutinated; sutures depressed, straight and radial; slightly biumbilicate; aperture an interiomarginal equatorial slit.

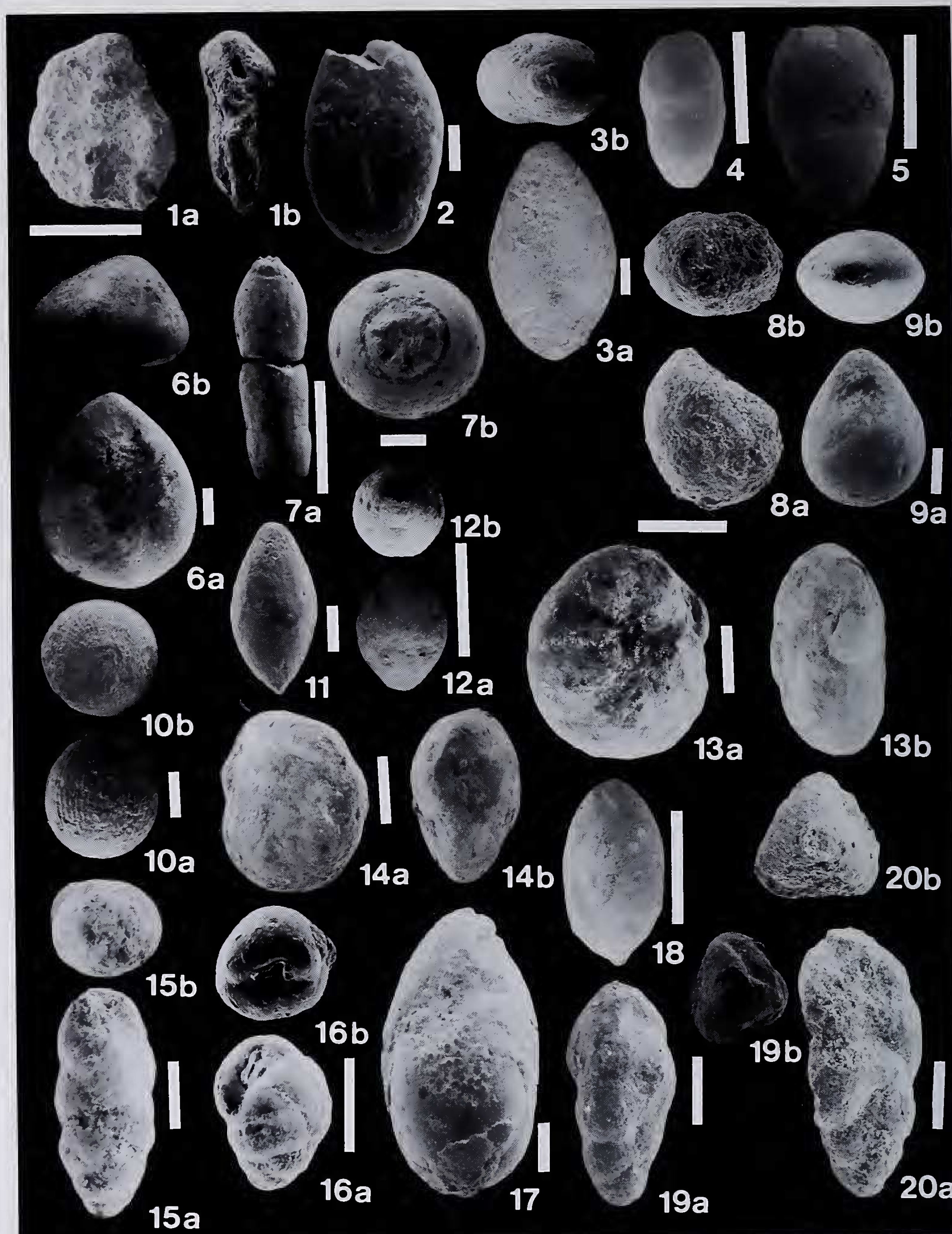
Remarks. This species was originally described from the Kyoragi Formation of the Amakusa Islands, Kyushu, as a species of *Cyclammina*. Because of the position of the aperture and reticulate wall, it is newly assigned to the current genus. Thin section showing a wide cavity in each chamber indicates that development of alveolar structure is quite weak (Figure 9.9c). It commonly occurred in the study sections, although it has never been recorded from the Poronai Formation in surface sections. It is highly possible that the present species has been assigned to other *Cyclammina* species by previous workers.

Cyclammina ezoensis Asano (Figure 9.3)

Cyclammina ezoensis Asano, 1951a, pl. 1, figs. 1a, b. —Asano, 1951b, p. 20, pl. 3, figs. 2a, b. —Ujiié and Watanabe, 1960, pl. 1, fig. 7. —Kaiho, 1984b, p. 45, 46, pl. 1, figs. 21a, b. —Kaiho, 1992b, p. 367, 368, pl. 1, figs. 5a, b.

Remarks. — This species is characterized by a compressed test with thin periphery. It was originally described from the Miocene Masuporo Formation in Hokkaido, and was commonly recovered from the Paleogene as well as Neogene formations of Japan. Neogene specimens sometimes attain much larger diame-

← **Figure 9.** Foraminifera from the Poronai Formation and the Ishikari Group appearing in the wells studied. Scale bars equal 100 μm except figs. 1, 3, 4, 5, 7, 8, 10, 11, 12, and 13, where bars equal 500 μm. **1.** *Ammobaculites* sp., from Kita-Akebono SK-1D, 3430 m. **2a–c.** *Alveolophragmium* sp. A, from MITI Umaoi, 3860 m. **3a–c.** *Cyclammina ezoensis* Asano, from MITI Umaoi, 4410 m. **4a, b.** *Cyclammina pacifica* Beck, from Kita-Akebono SK-1D, 3075 m. **5.** *Cyclammina pacifica* Beck, from Numanohata SK-4D, 3220 m. **6a, b.** *Cyclammina* sp. aff. *C. pusilla* Brady, from Kita-Akebono SK-1D, 3260 m. **7a–c.** *Cyclammina* sp., from Numanohata SK-4D, 3240 m. Note that this specimen has 15 chambers in the final whorl. **8a–c.** *Cyclammina* sp., from Numanohata SK-4D, 3760 m. Note that this specimen has 15 chambers and a bilaterally compressed test. **9a–c.** *Reticulophragmium amakusaensis* (Fukuta), from MITI Umaoi, 3740 m. **10.** "*Clavulina*" sp. from MITI Umaoi, 4060 m. **11a, b.** Fragment of last chamber of "*Clavulina*" -like species, from MITI Umaoi, 4060 m. Note the characteristic large cone-shaped last chamber. **12a–c.** *Poronaia poronaiensis* (Asano), from Numanohata SK-4D, 3240 m. **13a, b.** *Poronaia poronaiensis* (Asano), from Kita-Akebono SK-1D, 3210 m.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ters, as much as 4 mm, but commonly have fewer chambers in comparison with the Paleogene specimens.

Cyclammina pacifica Beck (Figure 9.4, 9.5)

Cyclammina pacifica Beck, 1943, pl. 98, figs.2, 3. —Asano, 1952, p. 33, pl. 3, figs. 1a, b, 2, pl. 5, figs. 11a, b. —Asano, 1958, pl. 13, fig. 3. —Kaiho, 1992b, p. 368, pl. 1, figs. 6a, b.

Cyclammina cf. *pacifica* Beck. —Asano, 1951a, p.7, figs. 24, 25. —Asano, 1951b, p. 20–21, pl. 3, figs. 5a, b. —Fukuta, 1962, p. 11, pl. 3, figs. 1–3. —Kaiho, 1984b, p.46, pl.2, figs. 1a, b.

Remarks.—This species has been commonly recorded from various Neogene and Paleogene formations throughout Japan. It shows compact arrangement of chambers. Although alveolar structure is rather poorly developed in the figured specimen (Figure 9.5), degree of development of alveolar structure varies among specimens.

Cyclammina* sp.** aff. ***C. pusilla Brady (Figure 9.6)

Aff. *Cyclammina pusilla* Brady, 1881, p. 53; Type figures: Brady, 1884, pl. 37, figs. 20–23.

Cyclammina pusilla Brady. —Kaiho, 1984b, p. 46, pl. 2, figs. 2a, b.

Remarks.—Specimens from the Poronai Formation have a smaller test size and subacute periphery, and are therefore distinguished from *C. pusilla*.

Poronaia poronaiensis (Asano) (Figure 9.12, 9.13)

Plectina poronaiensis Asano, 1952, p. 33, 34, pl. 4, figs. 12, 13. —Asano, 1958, pl. 13, figs. 5–7. —Fukuta, 1962, p.16, pl. 5, figs. 4, 5.

Poronaia poronaiensis (Asano). —Ujiié and Watanabe, 1960, p. 133, 134, pl. 2, figs. 1–8.

Plectotrochammina poronaiensis (Asano). — Loeblich and Tappan, 1964, p.279. —Kaiho, 1984b, p. 48, pl.2, figs. 10a–d.

Description.—Test free, short and broadly cylindrical, lower trochospiral in the early stage with four chambers, later biserial, each chambers imbricating to penultimate chambers; chambers inflated; wall finely agglutinated but occasionally includes coarse grains, internally imperfect alveolar structure developed; aperture, interiomarginal opening.

Remarks.—Specimens were occasionally deformed considerably. Loeblich and Tappan (1964) regarded the genus *Poronaia* as a junior synonym of *Plectotrochammina*, and later assigned both genera to their list of "Genera of Uncertain Status" (Loeblich and Tappan, 1987). However, *Poronaia* should be included in the family Textulariellidae because of possessing alveoli-like labyrinthic structure inside the test, while both *Plectina* and *Plectotrochammina* have a simple wall.

Trochammina sp. cf. ***T. asagaiensis*** Asano (Figure 10.1)

Cf. *Trochammina asagaiensis* Asano, 1949, p. 475, text-figs. 2a–4b.

Trochammina asagaiensis Asano. —Kaiho, 1984b, p. 47, pl. 2, figs. 5a–6b.

Remarks.—This species is characterized by its very low trochospiral and compressed test. However, specimens examined in this study and the specimens of Kaiho (1984b) show low trochospiral, obscure earlier whorls and inflated chambers compared to *T. asagaiensis*.

Quinqueloculina seminula compacta Serova (Figure 10.2)

Quinqueloculina seminulum (Linné) var. *compacta* Serova, 1960, pl. 3, figs. 7a–c.

Quinqueloculina weaveri Rau. —McDougall, 1980, p. 37, pl. 5, figs. 5–7.

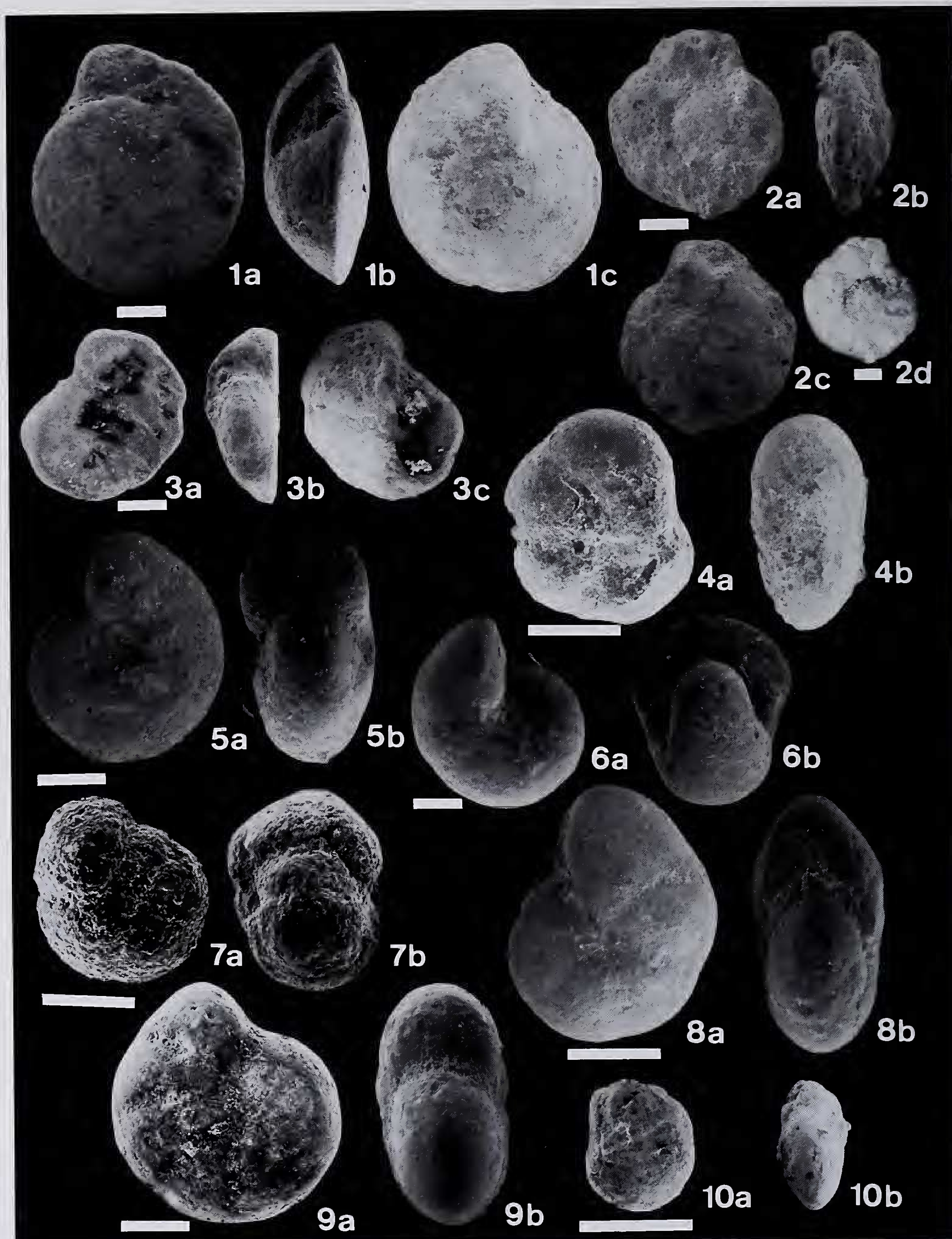
Quinqueloculina cf. *seminula compacta* Serova. —Kaiho, 1984b, p. 49, pl. 2, figs. 12a–c.

Dentalina sp. cf. ***D. subsoluta*** (Cushman) (Figure 10.7)

Cf. *Nodosaria subsoluta* Cushman, 1923, p. 74, pl. 13, fig. 1.

Dentalina cf. *subsoluta* (Cushman). —Kaiho, 1984b, p. 50–51, pl. 3, fig. 3. —Kaiho, 1992b, p. 373–374, pl. 1, fig. 14.

← **Figure 10.** Foraminifera from the Poronai Formation and Ishikari Group appearing in the wells studied. Scale bars equal 100 μm except figs. 1, 4, 5, 7a, 12, and 18, where bars equal 500 μm. **1a, b.** *Trochammina* sp. cf. *T. asagaiensis* Asano, from Numanohata SK-4D, 3220 m. **2.** *Quinqueloculina seminula compacta* Serova, from Numanohata SK-4D, 3260 m. **3a, b.** *Guttulina takayanagii* Kaiho, from Numanohata SK-4D, 3460 m. **4.** *Pseudopolymorphina* sp. A, from Numanohata SK-4D, 3285m. **5.** *Pseudonodosaria* sp. cf. *P. conica* (Neugeboren), from Numanohata SK-4D, 3305 m. **6a, b.** *Sigmoidella pacifica* (Cushman and Ozawa), from Numanohata SK-4D, 3400 m. **7a, b.** *Dentalina* sp. cf. *D. subsoluta* (Cushman), from Kita-Akebono SK-1D, 3360 m. **8a, b.** *Lenticulina* sp., from Kita-Akebono SK-1D, 3600 m. **9a, b.** *Fissurina* sp. cf. *F. marginata* (Montagu), from Kita-Akebono SK-1D, 3420 m. **10a, b.** *Lagena striata* (d'Orbigny), from MITI Umaoi, 3940 m. **11.** *Procerolagena* sp. cf. *P. gracilima* (Seguenza), from Kita-Akebono SK-1D, 3190 m. **12a, b.** *Glandulina laevigata ovata* Cushman and Applin, from Numanohata SK-4D, 3120 m. **13a, b.** *Globocassidulina globosa* (Hantken), from Numanohata SK-4D, 3240 m. **14a, b.** *Globocassidulina globosa* (Hantken), from Numanohata SK-4D, 3120 m. **15a, b.** *Bulimina schwageri* Yokoyama, from Numanohata SK-4D, 3120 m. **16a, b.** *Bulimina schwageri* Yokoyama (juvenile form), from Kita-Akebono SK-1D, 3120 m. **17.** *Globobulimina* sp., from MITI Umaoi, 4120 m. **18.** *Praeglobobulimina pyrula* (d'Orbigny), from Numanohata SK-3D, 3720 m. **19a, b.** *Angulogerina hannai* Beck, from MITI Umaoi, 3700 m. **20a, b.** *Angulogerina hannai* Beck, from MITI Umaoi, 3700 m.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Pseudonodosaria sp. cf. ***P. conica*** (Neugeboren) (Figure 10.5)
Cf. *Pseudonodosaria conica* (Neugeboren). —McDougall, 1980, p. 36, pl. 9, figs. 7, 8. —Kaiho, 1992b, p. 374, figs. 17a, b.
Cf. *Pseudoglandulina obtusissima* (Reuss). —Yoshida, 1957, p. 64, text-figs. 3–9.
Cf. *Pseudonodosaria shitakaraensis* Kaiho, 1984a, p. 118, pl. 8, figs. 1a, b.

Lagena striata (d'Orbigny) (Figure 10.10)
Oolina striata d'Orbigny, 1839, p.21, pl. 5, fig.12.
Lagena becki Sullivan. —McDougall, 1980, p. 35, pl. 7, figs. 1, 4.
Lagena striata (d'Orbigny). —Kaiho, 1984b, p. 51, 52, pl. 3, figs. 13a, b. —Kaiho, 1992b, p. 377, pl. 2, fig. 7.

Lagena sp. cf. ***L. laevis*** (Montagu)
Cf. *Vermiculum laeve* Montagu, 1803, p. 524; Type figure: Walker and Boys, 1784,pl. 1, fig. 9, as *Serpula* (*Lagena*) *laevis ovalis*.
Lagena laevis (Montagu). —Kaiho, 1984b, p. 51, pl. 3, figs. 11–13.

Remarks.—Specimens of this study have similar features to those of Kaiho (1984b), but are distinguished from the Recent *L. laevis* in its shorter test.

Procerolagena sp. cf. ***P. gracillima*** (Seguenza) (Figure 10.11)
Cf. *Amphorina gracillima* Seguenza, 1862, p. 51, pl. 1, fig. 37.
Lagena gracillima (Seguenza). —Kaiho, 1984b, p. 51, pl. 3, figs. 10a, b.
Cf. *Procerolagena gracillima* (Seguenza). —Jones, 1994, p. 62, figs. 19–22, 24–29.

Remarks.—This species is quite similar to *L. gracillima* of Kaiho (1984b), but different from the Recent *P. gracillima* in its shorter test.

Guttulina takayanagii Kaiho (Figure 10.3)
Guttulina takayanagii Kaiho, 1984a, p. 120, pl. 8, figs. 5a–d.

Pseudopolymorphina hokkaidoana Kaiho
Pseudopolymorphina hokkaidoana Kaiho, 1984a, p. 120, figs. 8a–c.

Sigmoidella pacifica (Cushman and Ozawa) (Figure 10.6)
Guttulina (*Sigmoidina*) *pacifica* Cushman and Ozawa, 1928, p. 19, pl. 2, fig. 13.
Guttulina cf. *pacifica* Cushman and Ozawa. —Fukuta, 1962, p. 23, pl. 7, figs. 9–10.
Sigmoidella pacifica Cushman and Ozawa. —Kaiho, 1984b, p. 58, fig. 53, pl. 4, figs. 12a–d.

Remarks.—This species is known from the Eocene formations from Kyushu to Hokkaido. It is common in the shallow marine facies in the lower part of the Poronai Formation, as discussed earlier. Since *S. pacifica* is also known from Recent shallow marine environments, it appears not to have changed habitat from the Eocene until the Recent. Although Jones (1994) regarded this species as a junior synonym of *Polymorphina elegantissima* Parker and Jones, I think these two species are distinguishable in the aspect of number of chambers visible from the the outside of the test.

Fissurina sp. cf. ***F. marginata*** (Montagu) (Figure 10.9)
Cf. *Vermiculum marginatum* Montagu, 1803, p. 524; Type figure: Walker and Boys, 1784, pl. 1, fig. 7.
Cf. *Fissurina marginata* (Montagu). —Loeblich and Tappan, 1953, p. 77, pl. 14, figs. 6–9.

Glandulina laevigata ovata Cushman and Applin (Figure 10.12)
Nodosaria (*Glandulina*) *laevigata* d'Orbigny var. *ovata* Cushman and Applin, 1926, p. 443, pl. 7, figs. 12, 13.
Glandulina laevigata ovata Cushman and Applin. —Ujiié and Watanabe, 1960, p. 129, 130, pl. 2, figs. 11, 12. —Kaiho, 1984b, pl.4, figs. 15a–c.

Globocassidulina globosa (Hantken) (Figure 10.13, 10.14)
Cassidulina globosa Hantken, 1875, p. 64, pl. 16, fig. 2.
Globocassidulina globosa (Hantken). —Kaiho, 1992b, p. 378, pl. 2, figs. 11a, b, pl. 5, figs. 17a, b.

Bulimina schwageri Yokoyama (Figure 10.15, 10.16)
Bulimina schwageri Yokoyama, 1890, p. 190, pl. 24, figs. 6–8. —Ujiié and Watanabe, 1960, pl. 2, figs. 16, 17, 18. —Kaiho, 1984b, p. 62–63, pl. 5, figs. 11–15. —Kaiho, 1992b, p. 379, pl. 3, figs. 2a, b.
Caucasina schwageri (Yokoyama). —Serova, 1976, p. 324, 325, pl. 1, figs. 6a–c.

← **Figure 11.** Foraminifera from the Poronai Formation and Ishikari Group appearing in the wells studied. Scale bars equal 100 μm except fig. 10 where bar equals 500 μm. **1a–c.** *Heterolepa poronaiensis* Kaiho, from Kita-Akebono SK-1D, 3340 m. **2a-d.** *Cibicides elmaensis* Rau, from Numanohata SK-3D, 3720 m. **3a–c.** *Cibicides* sp. A, from Kita-Akebono SK-1D, 3540 m. **4a, b.** *Nonionella japonica* (Yokoyama), from MITI Umaoi, 4000 m. **5a, b.** *Melonis affinis* (Reuss), from Numanohata SK-4D, 3340 m. **6a, b.** *Melonis pompilioides* (Fichtel and Moll), from Numanohata SK-4D, 3260 m. **7a, b.** *Pullenia eocenica* Cushman and Siegfus, from MITI Umaoi, 3980 m. **8a, b.** *Pullenia salisburyi* R. E. and K. C. Stewart, from Numanohata SK-4D, 3240 m. **9a, b.** *Cribroelphidium sorachiense* (Asano), from Numanohata SK-3D, 3720 m. **10a, b.** *Cribroelphidium ishikariense* (Kaiho), from Numanohata SK-3D, 3800 m.

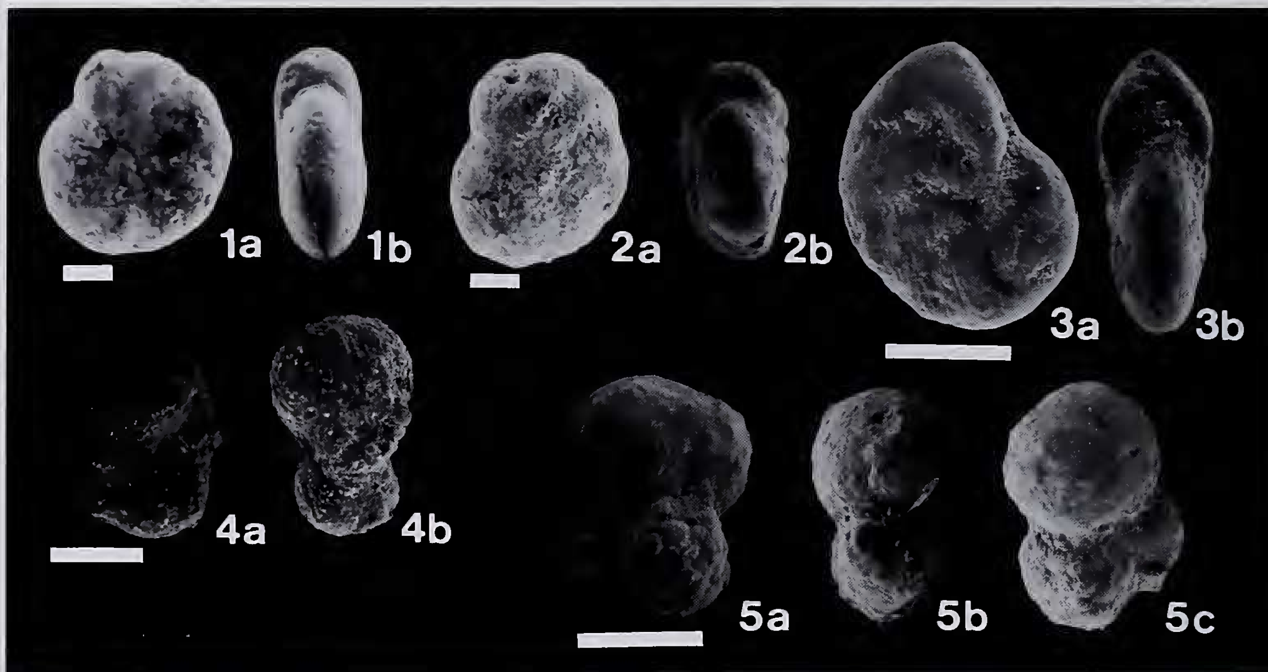

Figure 12. Foraminifera from the Poronai Formation and Ishikari Group appearing in the wells studied. Scale bars equal 100 μm. **1a, b.** *Cribroelphidium wakkanabense* (Kaiho), from Numanohata SK-4D, 3240 m. **2a, b.** *Cribroelphidium wakkanabense* (Kaiho), from Numanohata SK-3D, 3700 m. **3a, b.** *Cribroelphidium* sp. from Kita-Akebono SK-1D, 3410 m. Note that this specimen shows subacute periphery. **4a, b.** Planktonic foraminifera genus and species indeterminable. from MITI Umaoi, 4120 m. **5a–c.** *Subbotina* sp., from Kita-Akebono SK-1D, 3440 m.

Remarks. — This species has been recorded from Hokkaido to Kamchatka. As discussed by Kaiho (1984b), *B. schwageri* has three to four chambers in the first whorl, and is distinguished from the species of *Caucasina* which always have four chambers in the final whorl. Even if there is a phylogenetic relationship between *B. schwageri* and *Caucasina* species as pointed out by Serova (1976), emendation by reexamination of the type species of the genus *Caucasina* is necessary.

Praeglobobulimina pyrula (d'Orbigny) (Figure 10.18)

Bulimina pyrula d'Orbigny, 1846, p. 184, pl. 11, figs. 9, 10. —Asano, 1952, p. 41, figs. 10a, b. —Kaiho, 1984b, p. 62, pl. 5, figs. 10a–c.

Praeglobobulimina sp. cf. ***P. ovata*** (d'Orbigny)

Cf. *Bulimina ovata* d'Orbigny, 1846, p. 185, pl. 11, figs. 13, 14.
Praeglobobulimina ovata (d'Orbigny). —Kaiho, 1984b, pl. 6, fig. 2. —Kaiho, 1992b, pl. 3, fig. 5.

Angulogerina hannai Beck (Figure 10.19, 10.20)

Angulogerina hannai Beck, 1943, p. 607, pl. 108, figs. 26, 28.
Trifarina cushmani Todd and Knifer, 1952, p. 23, pl. 4, figs. 6a, b.
Trifarina maiyai Kaiho, 1984a, p. 122, 123, pl. 9, figs. 7a, b.
Trifarina hannai (Beck). —Kaiho, 1992b, p. 380, pl. 3, figs. 7a, b.

Remarks. — Relationship between *T. maiyai* and *T. hannai* follows the study of Kaiho (1992b). *T. cushmani* was originally reported from the Eocene in Chile and also reported from the Poronai Formation by Maiya (1979). Although Maiya (1979) did not figure any specimens, observation of his specimens by the present author revealed that they are conspecific with *A. hannai.* I regard *T. cushmani* as a junior synonym of *A. hannai* because of their similarity in morphology, such as test size and subacute periphery, on the basis of the original illustration by Todd and Knifer (1952).

Cibicides elmaensis Rau (Figure 11.2)

Cibicides elmaensis Rau, 1948, p. 173, pl. 31, figs. 18–26. —Fukuta, 1962, p. 25, pl. 8, figs. 3a, b, 7a, b.
Cibicides biconbexus Kaiho, 1984a, p. 124, pl. 9, figs. 7a–c.
?*Cibicides yabei* Asano, 1952, p. 43, pl. 4, figs. 1a–c.

Remarks.—Cibicides yabei Asano (1952) was described from the basal part of the Poronai Formation, but was not recorded by Kaiho (1984a, b) who studied the same formation in the same area. As discussed by Asano (1952), *C.*

yabei is distinguished from *C. elmaensis* in lacking shell material filling the umbilical area, but I think that this is insufficient to separate *C. yabei* as a different species.

Nonionella japonica (Yokoyama) (Figure 11.4)

Pilvulineria japonica Yokoyama, 1890, p. 192, pl. 24, figs. 15 a–c.

Nonionella japonica (Yokoyama). —Ujiié and Watanabe, 1960, p. 131, pl. 3, figs. 4a–c. —Kaiho, 1984b, p. 72, pl. 7, figs. 4a–c.

Melonis affinis (Reuss) (Figure 11.5)

Nonionina affinis Reuss, 1851, p. 72, pl. 5, figs. 32a, b.

Nonion aimonoi Matsunaga, 1963. p. 109. pl. 37, figs. 2a, b.

Melonis crassus Kaiho, 1984a, p., pl. 2, figs. 6a, b, 129. —Kaiho, 1992b, p. 383, pl. 4, figs. 6a, b.

Melonis pompilioides (Fichtel and Moll) (Figure 11.6)

Nautilus pompilioides Fichtel and Moll, 1798, p. 31, pl. 2, figs. a–c.

Nonion pompilioides shimokinense Asano, 1958, p. 71, pl. 13, figs. 14a, b.

Melonis pompilioides (Fichtel and Moll). —Kaiho, 1984b, p. 74, figs. 12a, b. —Kaiho, 1992b, p. 383, pl. 4, figs. 7a, b, pl. 6, figs. 5a, b.

Remarks.—Recent *Melonis pompilioides* lives in water deeper than the middle bathyal zone around Japan (Akimoto and Hasegawa, 1989). However, in the Poronai Formation, this species occurred in shallow marine fossil assemblages. The Paleogene *M. pompilioides* has a larger test than the Neogene specimens but in other biometrical aspects it fits the Recent *M. pompilioides* studied by Hasegawa (1983).

Pullenia eocenica Cushman and Siegfus (Figure 11.7)

Pullenia eocenica Cushman and Siegfus, 1939, p. 31, pl. 7, figs. 1a, b. —Asano, 1958, pl.11, figs. 13a, b.

Pullenia cf. *quinqueloba angusta* Cushman and Todd. —Fukuta, 1962, p. 25, pl. 8, figs. 4a, b.

Pullenia compressiuscula Reuss. —Ujiié and Watanabe, 1960, p. 131, pl. 3, Fig. 5.

Remarks. — This species is distinguished from *P. compressiuscula* and *P. quinqueloba angusta* in having a broadly rounded periphery and fewer chambers in the final whorl. All specimens examined in this study are replaced with pyrite.

Pullenia salisburyi R. E. and K. C. Stewart (Figure 11.8)

Pullenia salisburyi R. E. and K. C. Stewart, 1930, p. 72, pl. 8, figs. 2a, b. –Asano, 1958, pl. 8, fig. 17. –Ujiié and Watanabe, 1960, p. 15, pl. 3, fig. 5. –Kaiho, 1984b, p. 72, pl. 7, figs. 7a, b.

Remarks. — There are many records of this species around the North Pacific region, ranging in age from the Eocene to Recent. There has, however, been confusion among researchers on the relationship between *P. salisburyi* and *P. subcarinata* (d'Orbigny), which was originally described as *Nonionina subcarinata*. This study follows the views of the previous workers of the Japanese Paleogene.

Heterolepa poronaiensis Kaiho (Figure 11.1)

Heterolepa poronaiensis Kaiho, 1984a, p. 128, pl. 11, figs. 5a–c, 7a–c.

Cribroelphidium ishikariense (Kaiho) (Figure 11.10)

Elphidium ishikariense Kaiho, 1984a, p. 125, pl. 10, figs. 2a, b.

Remarks.—This is the first record of this species from the Poronai Formation.

Cribroelphidium sorachiense (Asano) (Figure 11.9)

Nonion sorachiense Asano, 1954, p. 48, figs. 4a–5c.

Elphidium sorachiense (Asano). —Ujiié and Watanabe, 1960, p. 132, pl.3, figs. 11, 12. —Kaiho, 1984b, p. 70, 71, pl. 6, figs. 12a, b.

Cribroelphidium wakkanabense (Kaiho) (Figure 12.1, 12.2)

Elphidium asanoi Kaiho, 1984a. p. 124, 125, pl. 10, figs. 1a, b. (non *E. asanoi* Matsunaga, 1963)

Elphidium wakkanabense Kaiho, 1992a, nom. nov. p.143.

Remarks.—This species was originally described from the Wakkanabe Formation, Ishikari Group as *Elphidium asanoi*, and was first recorded from the Poronai Formation in the present study. *Elphidium wakkanabense* was proposed as a new name replacing *E. asanoi* Kaiho. The homonymic relationship with *E. asanoi* Matsunaga (1963) is still a primary one even though Matsunaga's species has features which cause me to remove it to the genus *Cribroelphidium* based on my observation of Neogene specimens.

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Appendix 1. Distributions of foraminifera in the

*1 : Barren Foraminifera ; *2 : *Bulimina schwageri-Angulogerina hannai* ; *3 : Minaminaganuma Formation

	well name	Numanohata SK-3D																		Numanohat					
	Depth of Formation boundary (wireline depth in meter)		3649.0m								3804m										3070.5m				
	Formation	*3	Poronai Formation								Ishikari Group									*3					
	Assemblage Zone	*1	*2	*G. subgl.-C. sorachi.*					*E. subamakusaensis - H. crassiformis*									*1		*1	*Bulimina schwageri-A*				
	Sample Depth (drilling depth in meter)	3640	3660	3680	3700	3720	3740	3760	3780	3800	3820	3840	3860	3880	3900	3920	3940	3960	3980	3060	3080	3100	3110	3120	3140
Ostracoda																								3	
	AGGLUTINATED																								
Bathysiphon	*eocenica* Cushman and Hanna										1														
?Ammodiscus	sp. indet.																								1
Glomospira	sp.																								
Cribrostomoides	sp. cf. *C. cretacea* Cushman and Goudkoff																				1				2
Evolutinella	*subamakusaensis* (Fukuta)									6						2									
Evolutinella	sp. cf. *E. subamakusaensis* (Fukuta)											1													
Haplophragmoides	*crassiformis* Kaiho								2	3						1		1						1	3
Haplophragmoides	*rugosus soyaensis Yasuda*																								
Haplophragmoides	sp. cf. *H. rugosus soyaensis* Yasuda									1															
Haplophragmoides	*tanaii* Kaiho				2																				
Haplophragmoides	sp. cf. *H. tanaii* Kaiho																								
Haplophragmoides	sp. A																						1		
Haplophragmoides	sp. B				4			1					2												
Haplophragmoides	sp. D										1	2	1												
"Haplophragmoides"	spp.				18	9	10	16	11	5	12	19	5	1	2	1		1				1	1	2	
Budashevaella	sp. aff. *B. multicamerata* (Voloshinova)																								6
Budashevaella	*symmetrica* (Ujiie and Watanabe)																							3	3
Budashevaella	sp. cf. *B. symmetrica* (Ujiie and Watanabe)																								
Budashevaella	sp. indet.																								
Recurvoidella	sp. cf. *R. lamella* (Grzybowski)								1	13		5													
Reticulophragmium	*amakusaensis (Fukuta)*							2	2														1		6
Reticulophragmium	sp. cf. *R. amakusaensis* (Fukuta)																								
Cyclammina	*ezoensis* Asano																								
Cyclammina	sp. cf. *C. ezoensis* Asano						3																		
Cyclammina	*pacifica* Beck		1			1	2			1					1								2	4	5
Cyclamminidae *genus et sp.* indet.							3	9	1	4	1	7									1		5	10	11
Poronaia	*poronaiensis* (Asano)					1																	1		
Poronaia	sp. cf. *P. poronaiensis* (Asano)					1																	1		
Trochammina	sp. cf. *T. asagaiensis* Asano			4	1		11																		
Trochamminidae *genus et* sp. indet.				4	10	5		6													1				
Aggulutinated miscellaneous				36	24	52	67	102	99	125	17	34	2	6								2	3	26	34
	PORCELLANEOUS																								
Quinqueloculina	*seminula compacta* Serova																								
Ouinqueloculina	sp. indet.											1													
	CALCAREOUS HYALINE																								
?Dentalina	spp.			1																					
Pseudonodosaria	sp. cf. *P. conica* (Neugeboren)																								
Pseudonodosaria	sp. indet.																								
Lagena	sp. cf. *L. laevis* (Montagu)				1																				
Procerolagena	sp. cf. *P. gracilima* (Seguenza)																								
Guttulina	*takayanagii* Kaiho																								
Guttulina	sp. cf. *G. takayanagii* Kaiho																								
Pseudopolymorphina	sp. A																								
Sigmoidella	*pacifica* Cushman and Oazwa																							2	
Polymorphinidae *genus* et *sp.* indet.								1	2	5	1														
Fissurina	sp. cf. *F. marginata* (Montagu)																								
Glandulina	*laevigata ovata* Cushman and Applin				1																			1	
Glandulina	sp. indet.						2			1															
Globocassidulina	*globosa* (Hantken)		1	1	1		1																	1	1
Globocassidulina	spp.		1																						1
Bulimina	*schwageri* Yokoyama		1																		16		3	25	17
Praeglobobulimina	sp. cf. *P. ovata* (d'Orbigny)																								
Praeglobobulimina	*pyrula* d'Orbigny		2	1		1																			
Praeglobobulimina	sp. indet.									1															
Buliminidae *genus* et *sp.* indet.																									
Angulogerina	*hannai* Beck																							5	7
Cibicides	*elmaensis* Rau				2	1	1																		
Melonis	*affinis* (Reuss)																								
Melonis	*pompilioides* (Fichtel and Moll)				1			2		3		1													
Melonis	sp. indet.						1																		
Pullenia	*eocenica* Cushman and Siegfus									1															
Pullenia	*salisburyi* R.E. and K.C.Stewart																								
Cribroelphidium	*ishikariense* (Kaiho)									1															
Cribroelphidium	*sorachiense* (Asano)			17	3	15	6	20		13	8	5	2		2		1								
Cribroelphidium	sp. cf. *C. sorachiense* (Asano)								8																
Cribroelphidium	*wakkanabense* Kaiho				1			12	2			4												1	
Cribroelphidium	spp.			13	4	3		3	12	3	4		1		1										
Calcareous miscellaneous			4	2	1		10	13	13	15		7	2	3		1					1		2	5	5
	Percentage of Agglutinated Foraminifera		10	56	80	78	82	73	76	79	71	79	67	70	50	80	0	100			15	100	75	53	70
	Percentage of Porcellaneous Foraminifera		0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0			0	0	0	0	0
	Percentage of Calcareous Foraminifera		90	44	20	22	18	27	24	21	29	20	33	30	50	20	100	0			85	0	25	47	30
	Total population of Foraminifera		10	79	74	89	117	187	153	201	45	86	15	10	6	5	1	2			20	3	20	86	102
	Diversity (Species Richness)		4	4	10	5	5	5	3	7	3	4	3	0	2	2	1	1			2	0	5	9	9
	Diversity (Simpson's Index for Diversity)		3.6	1.7	7.4	1.6	2.7	2.5	3	3.5	1.5	3.6	2.8		1.8	1.8	1	1			1.1		4	2.7	5.5

wells Numanohata SK-3D and Numanohata SK-4D.

a SK-4D

3507.0m — 3678.5m Fault — 3698.0 m

Poronai Formation | Ishikari Group | Poronai | Ishikari Group

\ngulo. hannai | Globoca. globosa- Cribroel. sorachiense | *Evolutinella subamakusaensis - H. crassiformis* | *1

3160	3180	3200	3220	3240	3260	3270	3285	3305	3320	3340	3360	3380	3400	3420	3440	3460	3480	3500	3520	3540	3560	3580	3600	3620	3640	3660	3680	3700	3720	3740	3760	3780	3800	3820	3840	3880	3900
	1	1?			1	1		3							1																						
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				4	1	5	8	1		1				30	22	21	42	33	3	15	7	2	32	12	3	2	23	54	45	86	6	2	3	2	1	1	
															4	7	12	17	13	12	3		18	2	1	3	4	11	6	19	1			1	1		
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3			4	9		4		5			2					1																					
	2				3																																
				1											1																						
2		4		17	21	21			29	5	4			1	13	17	5	196	1	28	1		70	14	1	2	14	60	80	83	19	2	2	2	7		
	2	5	3	4	1		3	2		4	1	1		4	1	5			3	1		2					2	4									
					2																																
		1	2											1														1	1								
	1	5	5	2	1				1		1			1		1												2									
	2	2	3	4	2	3	1	7	2	2				6			10			1										3						1	
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							2	2	6																												
		1																																			
14	13	15	22	31	45	48	148	140	9	19	3	1	1	12	2	20	32	15	3	4			4				6	7	6	6	1						
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		1								1																											
1	3			10	21	10	4	3	1	1																											
									1																												
									1					1													1										
	2		4	12		8	13	8			4																										
	7	11	4	20	24	29	22	21	7	42	23	3	5			2											1										
1		4		2	3	3				3	4																										
		1			3	7		9				1					3			1									1								
5	7	4	8	2	5	9	8	13	7	7	4		1			2	4		1				3									1					
68	43	54	74	58	53	48	77	73	67	42	28	74	27	95	98	92	91	100	96	97	100	100	96	100	100	100	92	100	99	100	100	86	100	100	100	100	
0	0	0	0	1.3	0.6	2.2	0	1.8	2.5	1.8	0	0	13	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
32	57	46	26	41	47	50	23	28	31	57	72	26	60	3.4	2.3	7.8	9.1	0	3.8	2.8	0	0	3.8	0	0	0	7.5	0	0.7	0	0	14	0	0	0	0	
34	47	70	78	158	172	181	256	282	81	113	54	19	15	59	44	79	132	287	26	72	12	5	133	29	5	7	53	159	147	210	28	7	5	5	10	2	
8	8	11	8	16	14	11	18	16	7	10	8	2	4	6	3	8	4	2	3	3	2	2	2	2	2	2	5	4	2	2	2	1	1	2	2	1	
8.4	5.4	8.8	8.7	8.2	5.1	5	7.8	8.3	4.7	2	2.4	1.6	2.6	1.6	1.5	2.9	1.8	1.8	1.9	2.1	1.7	2	1.9	1.3	1.6	1.9	1.7	1.8	1.3	1.4	1.3	1	1	1.8	2	1	

Casing shoe depth: 3360m

Appendix 2. Distributions of foraminifera

*1 Barren foraminifera; *2 Minaminaganuma Formation

well name		KITA-AKEBONO SK-1D																							
Depth of Formation boundary (wireline depth in meter)		3067.0m																							
Formation		*2	Poronai Formation																						
Assemblage Zone		*1	Rare for aminifera									*Bulimina schwageri - Angulogerina hanna*													
Sample Depth (drilling depth in meter)		3060	3075	3080	3100	3120	3140	3150	3160	3170	3180	3190	3200	3210	3220	3230	3240	3250	3260	3270	3280	3290	3300	3310	3320
Ostracode								1																	
	PLANKTONIC																								
Subbotina	sp. indet.																								
?PLANKTONIC *miscellaneous*																									
	AGGLUTINATED																								
Bathysiphon	*eocenica* Cushman and Henna												2	1											
Bathysiphon	*vemoni* Hamlin																								
?Bathysiphon	spp.											1	2	2											
Placentammina	sp. A														2									1	
Ammodiscus	spp.											1	1	1	1								1		
Glomospira	spp.														1			3	1						
Reophax	*tappuensis* Ȧsano																								2
Reophax	sp. cf. *R. teppuensis* Asano														1										7
Reophax	sp.																			1				3	
Cribrostomoides	sp. cf. *C. cretacea* Cushman end Welters												1	2		2	8	7		2		1			
Evolutinella	*subamakusaensis* (Fukuta)											1	8	26	6	2	24	6	1	2	1		3	1	8
Evolutinella	sp. cf. *E. subamakusaensis* (Fukute)																								
Haplophragmoides	*crassiformis* Kaiho																								
Haplophragmoides	sp. cf. *H. crassiformis* Kaiho										5	39	22	11	27	6	17	22	3		7	6	4		8
Haplophragmoides	*rugosus soyaensis* Yasuda																1								3
Haplophragmoides	sp. cf. *H. tanaii* Kaiho																1								
Haplophragmoides	*yokoyamai* Keiho														1										
Haplophragmoides	sp. A												1												
Haplophragmoides	sp. B																								
Haplophragmoides	sp. D					1	3											1		1	5	2	1		
Haplophragmoides	spp.			1	2	2	60	13			4	45		71	28	20	20	4	50	462	94	81	37	101	24
Discammina	sp. indet.																								
Budashevaella	sp. eff. *B. multicameratus* (Voloshinova)												8	8						2					
Budashevaella	*symmetrica* (Ujiie and Watanebe)											1	17	22	2	2	8	4	1	1					
Recurvoides	sp. A														7	2	1								
Recurvoides	spp.							1										1							
Recurvoidella	sp. cf. *R. lamella* (Grzybowski)					5	30	3						5	8		11	7	43	62	17	19	12	48	59
?Ammobaculites	spp.																								
"*Clavulina* "	sp. indet.													3											
Alveolophragmium	spp.																								
Reticulophragmoides	*amakusaensis* (Fukuta)							1			6	10	16	19	17	7	6	2		1		7	2	2	16
Cyclammina	*ezoensis* Asano																		1		3		1		
Cyclammina	*pacifica* Beck		1	1			2	2			3	12	14	17	17	10	4	5	2		7	2	2	3	3
Cyclammina	sp. aff. *C. pusilla* Brady																	1	1					5	
Cyclamminidae genus et sp. indet.			1		1	6	10	7			3	12	21	25	10	13	6	7	3	6	11	10	11	10	17
?Oorothia	sp. indet.													1						1					
Poronaia	*poronaiensis* (Asano)													13	2	3			1						
Trochammina	sp. cf. *T. asagaiensis* Asano																								
Trochammina	spp.											1		7	1										
fragment *Clavulina* like species's aperturel end																						1		3	
Agglutinated *miscellaneous*			1		2	15	6	8			3	14	24	106	94	23	36	18	27	27	24	5	9	62	72
	PORCELLANEOUS																								
Ouinqueloculina	*seminula compacta* Serova					1		5					2							1	2				
Ouinqueloculina	spp.					1						2	38					1							
Miliolidae *miscellaneous*												2													
	CALCAREOUS HYALINE																								
Oentalina	sp. cf. *O. subsoluta* (Cushman) of Kaiho, 1984																								
"*Oentalina* "	spp.(fragments)												1	8											
Pseudonodosaria	*conica* (Neugeboren)																								
?Astacolus	sp.																								
Lenticulina	sp.																								
Marginulina	sp.																								
Lagena	sp. cf. *L. laevis* (Montagu)					1						2										1		1	1
"*Lagena* "	spp.					1		1						2											
Procerolagena	sp. cf. *P gracilima* (Seguenza)											1													
Guttulina	*problema* (d'Orbigny)															1				1					
Guttulina	*takayanagii* Kaiho				1																				
Guttulina	sp. cf. *G. takayanagii* Keiho															1									
"*Guttulina* "	spp.													1											
Pseudopolymorphina	*hokkaidoana* Kaiho					1																			
Sigmoidella	*pacifica* Cushman end Ozawa					1						1	1	2	2								1	2	1
Fissurina	sp. cf. *F. marginata* (Montagu)																								
Glandulina	*laevigata ovata* Cushman and Applin										1	1	1	1					4		2			1	
Globocassidulina	*globosa* (Hantken)							1		1			2	3					1	7	4		4		
Globocassidulina	spp.														1					2					
Bulimina	*schwageri* Yokoyama					1						4	50	16	5	2	4		9	4	3		1	1	1
Praeglobobulimina	*pyrula* (d'Orbigny)																								
Globobulimine & Preglobobulimina spp.																			3	5					
Angulogerina	*hannai* Beck											13	33	20	5	1					2	3	1	1	
Cibicides	sp. A																								
Cibicides	spp.																								
Nonionella	*japonica* (Yokoyama)																								
Melonis	*affinis* (Reuss)																							2	2
Melonis	*pompilioides* (Fichtel and Moll)										1	2		2	1				1	6	6		1	2	4
Pullenia	*eocenica* Cushman end Siegfus												2								1			4	1
Pullenia	*salisburyi* R.E. and K.C.Stewart							1					2	1					11	10	8	6	2	7	6
Heterolepa	*poronaiensis* Kaiho																								
Cribroelphidium	*ishikariense* Keiho																								
Cribroelphidium	*sorachiense* (Asano)		2		3	9	9	10			1		1	5	1				2	3	8	8	12	15	6
Cribroelphidium	*wakkanabense* Kaiho		4				1	2																	
Cribroelphidium	spp.					13															1				
Calcareus *miscellaneous*						10	3		1			7	7	7	1	2	2	2	32	19	11	9	2	7	6
Percentage of Planktonic speices		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percentage of Agglutineted species		0	33.3	100	55.6	43.3	89.5	63.6	0	0	88.9	79.7	49.5	83.3	93.4	92.8	96	96.7	68	90.7	77.9	83.2	77.6	84.8	88.7
Percentage of *Calcareous* benthic species		0	66.7	0	44.4	58.2	10.5	36.4	100	100	11.1	20.3	50.5	16.7	6.64	7.22	4.03	3.3	32	9.27	22.1	16.8	22.4	15.2	11.3
Total population		0	9	2	9	67	124	55	1	1	27	172	277	408	241	97	149	91	197	626	217	161	107	282	247
Diversity (Species Richness)			3	1	2	7	4	7	0	1	5	11	17	16	13	11	8	7	12	13	13	8	12	15	13
Diversity (Simpson's Index for Diversity)			2.33	1	1.6	3.57	2.04	4.31		1	3	5.21	5.78	9.58	7.26	6.02	5.02	6.02	2.92	2.61	8.28	4.54	5.59	3.48	3.26

Casing shoe depth: 3096m

in the well Kita-Akebono SK-1D.

3628.0m

Ishikari Group

…ai	Globocassidulina globosa - Cribro. sorachiense																E. subamakusaensis - H. crassiformis														Barren				
3330	3340	3350	3360	3370	3380	3390	3400	3410	3420	3430	3440	3460	3480	3500	3520	3540	3560	3580	3600	3620	3640	3660	3680	3700	3720	3740	3760	3780	3800	3825	3840	3860	3880	3900	3940
				5?	1	1		3	5	2	3	2	4		6	1			1	1?															
											1																								
											2																								
																		1																	
	1							1																											
		1	2	3		1	3			1	1	3		1				6		1															
																							2												
	2	2	1				1				2					1						1													
	1						5																												
17	4	4	1	1	1	14	17	13	11	5	1		5		3	1	6	22	36	6	7	4	51		1	1	2			1					
							17	10	17	2		1					15	18	16	10	2	17	10		2										
		1	4	30	5	7					2				2	2																			
9	23	15					4				2																								
							6																												
						1																													
		2			2	3	4	8	4	8	4	3	5	3	1	2				1															
		2			2	1			1	2										2															
56	98	78	117	96	197	118	158	171	216	198	462	169	162	109	195	171	293	150	162	29	5	34	31		1	1	1	1							
																		1																	
8	6	7	6	5	2	6	6		2	6	1	1					1							1											
25	11	260	339	127	235	315	320	467	463	378	365	26	18	35	28	25	65	267	201	23	15	253	12		3										
1								1		1		1	2	1						1															
		2																		2															
4	3	4	3	1	7	1	6	3	4	4		2	2		1	1	1	2	2	2			1		1			1							
							3	1		1	1							3																	
3	1	3	2	1		1	4		4	2	3				3			2	1	1			1												
																		1																	
8	16	6	1	5	6	9	8	4	6	8	8	6	3	3	5	3	5		5	3															
																				1															
	1												2																						
								1																											
		1																1		2	1														
38	90	70	46	80	67	121	120	70	121	140	55	38	43	37	49	40	86	67	87	10	26	10	31		2		2	1	1						
			2	4	10			1	4	1	2				7	3	1	1					1												
			1																																
	1				2			2																											
															1																				
				1																															
																			1																
					1																														
1						1				1					1	1	1							1											
									1																										
1					1									2																					
													2		3																				
																											1								
	1			1	1		1			1			2	1	7	2		1				1													
									1										1		1														
2	1	3			1	4	8	2	8						1		1	1	3																
1	1	13	29	13	33	34	13	22	9	31	9	2		1		2		3	1	1		2													
		3	1								2				1																				
2				1			4	1		1		1	2	3					2																
																			1																
		9	2	3	1	1		1	1	1				1																					
1											1					2		2																	
																1																			
						1																													
																1																			
	1	3																																	
1	3	10	7	26	60	15	6	1				1		1				1			1														
		2		2	1		3		2	1	4				1			1																	
		4	5	10	4	13	18	2	4	5	2			1	3	1	1	3	7																
1	1		1																																
																			1																
6	5	10	52	55	90	71	23	20	8	11	21	58	26	29	10	11			1	3	3	6	6		1										
		3	7	8	7	6		2	2		15	30	51	34	18	9			3	3															
						1		1					10	5	7			10	14																
4	10	13	18	16	19	29	16	30	27	10	22	6	4	20	15	7	7	8	20	1	2	2	4				1								
0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89.3	91.5	86.3	81	71.4	69.4	77.1	87.9	89.6	93.1	92.3	91.8	71.4	71.4	65.9	79.3	86	97.7	94.6	90.8	92.2	89.2	96.7	92.7	50	90.9	100	71.4	100	100	100	0	0	0	0	0
10.7	8.54	13.7	19	28.8	30.8	22.9	12.1	10.2	6.91	7.67	7.89	28.8	28.6	34.1	20.7	14	2.28	5.42	9.4	7.84	10.6	3.33	7.33	50	9.09	0	28.8	0	0	0	0	0	0	0	0
187	281	531	647	489	755	776	778	835	912	821	989	350	339	287	362	286	483	572	585	102	65	330	150	2	11	2	7	3	1	1	0	0	0	0	0
14	14	18	13	15	16	15	18	14	18	17	14	10	9	10	14	13	8	16	14	10	5	5	8	2	4	1	1	1	0	1					
5.93	5.27	1.75	1.78	3.25	3.06	2.25	2.09	1.4	1.36	1.49	1.39	3.3	3.6	3.79	5.74	4.48	1.88	1.55	1.81	4.04	2.91	1.24	2.33	2	4	1	1	1		1					

Appendix 3. Distributions of

*1 : Barren Foraminifera ; *2 : Minaminaganuma Formation

well name		MITI Umaoi																								
Depth of Formation boundary (wireline depth in meter)		3640.0m																								
Formation		*2	Poronai Formation																							
Assemblage Zone		*1	*Bulimina schwageri - Angulogerina hannai*																							
Sample Depth (drilling depth in meter)		3620	3640	3660	3680	3700	3720	3740	3760	3780	3800	3820	3840	3860	3880	3900	3920	3940	3960	3980	4000	4020	4040	4060	4080	4100	4120
Ostracoda																?6	?2		?2								
	PLANKTONIC																										
Planktonic foraminifera genus et sp. indet.																											1
	AGGLUTINATED																										
Bathysiphon	*eocenica* Cushman and Hanna					1					1		3	5		1				5	2						
?Ammodiscus	sp. indet.								1				1														
Glomospira	sp.																				1	1				2	
Reophax	sp.																					1					
Cribrostomoides	sp. cf. *C. cretacea* Cushman and Goudkoff																5										
Evolutinella	*subamakusaensis* (Fukuta)		1	1							1	1		1	1											40	6
Evolutinella	sp. cf. *E. subamakusaensis* (Fukuta)																4	3									
Haplophragmoides	*rugosus soyaensis* Yasuda																										
Haplophragmoides	sp. cf. *H. rugosus soyaensis* Yasuda																		2								3
Haplophragmoides	*crassiformis* Kaiho																				2	1	1				
Haplophragmoides	sp. cf. *H. crassiformis* Kaiho						11		5			4	6														
Haplophragmoides	*tanaii* Kaiho																				3						6
Haplophragmoides	*yokoyamai* Kaiho												5	1					1								
Haplophragmoides	sp. B																			1				1			
Haplophragmoides	sp. D											1												3			
"*Haplophragmoides* "	spp.		6	6	3	12	8	5		24	7	3	14	32		40	17	25	3	10	10	7		3		10	11
Ammobaculites	sp. indet.																										
Budashevaella	sp. aff. *B. multicamerata* (Voloshinova)									4				9			11				7						
Budashevaella	*symmetrica* (Ujiie and Watanabe)						2			1		3	6		2	7	4		2		15	1	2				
Budashevaella	sp. indet.																					3					
Recurvoides	sp. A									1						1	1										
Recurvoidella	sp. cf. *R. lamella* (Grzybowski)							5		2	2	4	4	1		14			2	3	2	10	2	9	2	4	32
Alveolophragmium	sp. A													2	1												
Reticulophragmium	*amakusaensis* (Fukuta)			2	2	1	2	1	2	11	4	5	9	8	1		4	6	10	10	8	2	1			2	2
Cyclammina	*ezoensis* Asano															1									1		
Cyclammina	*pacifica* Beck			1			6	3		14	11	9	4	23	6	10	8	8	11	12	6	5			2		4
Cyclamminidae genus et sp. indet.				7	3	8	7	3		27	6	13	18	14	2	13	13	6	13	12	9	6	1	1	6	6	8
Poronaia	*poronaiensis* (Asano)															5	2										
Trochammina	sp. cf. *T. asagaiensis* Asano																				1	1					
Trochamminidae genus et sp. indet.												4		6													
?"*Clavulina* "	sp. A													1													
Clavulina	sp. indet.													1													
fragment of "*Clavulina* " like apertural end															1		1							1			
Agglutinated miscellaneous			16	4	21	26	39	47	21	77	30	40	56	107	30	153	74	25	32	73	109	71	18	15	8	40	101
	PORCELLANEOUS																										
Quinqueloculina	sp. indet.									1						1											
	CALCAREOUS HYALINE																										
?Dentalina	spp.															1			3		1						
Lagena	*striata* (d'Orbigny)																	1									
Lagena	sp. cf. *L. laevis* (Montagu)																	1									
Guttulina	*takayanagii* Kaiho					1												1									
Guttulina	sp. cf. *G. problema* (d'Orbigny)																										
Pseudopolymorphina	sp. indet.												1														
Sigmoidella	*pacifica* Cushman and Oazwa				1					2		1		2	2	3	1	1	1	1							1
Polymorphinidae genus et sp. indet.														4	1					2							
Glandulina	*laevigata ovata* Cushman and Applin																										
Glandulina	sp. indet.																							1			
?Cassidulinoides	sp.																										1
Globocassidulina	*globosa* (Hantken)				1	2			1	6		2	1	2	1	2			1	2							
Globocassidulina	spp.													2		1				1							
Bulimina	*schwageri* Yokoyama			13	15				1	40	13	33	8	9	57	97		2	59	54	30	4			1	1	6
Globobulimina	sp. indet.																										1
Buliminidae genus et sp. indet.								1	1					4								1					
Angulogerina	*hannai* Beck			1	4	12				1		1			4	23			20	34	18	4	1		1	1	13
Nodogeneria	sp. cf. *N. lepidula* (Schwager)												1														
"*Nonion* "	sp. indet.												1														
Nonionella	*japonica* Yokoyama																				1						
Melonis	sp. cf. *M. affinis* (Reuss)																	3									
Melonis	*pompilioides* (Fichtel and Moll)																										3
Melonis	sp. indet.																		2	3							
Pullenia	*eocenica* Cushman and Siegfus																			1							
Pullenia	*salisburyi* R.E. and K.C.Stewart							2																	1		3
Cribroelphidium	*sorachiense* (Asano)							1		7	1			4		1		2	2	3			1				
Cribroelphidium	spp.			2										1		2			3								
Calcareous miscellaneous				2	5	4			4	14	9	7	9	3	2	31		6	14	14	8		1		2	3	8
Percentage of Agglutinated Foraminifera			100	54	53	72	100	94	81	69	73	66	86	87	40	60	99	81	42	52	75	92	89	97	79	95	83
Percentage of Porcellaneous Foraminifera			0	0	0	0	0	0	0	0.4	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Percentage of Calcareous Foraminifera			0	46	47	28	0	5.9	19	30	27	34	14	13	60	40	0.7	19	58	48	25	7.6	11	2.9	21	4.6	17
Total population of Foraminifera			23	39	55	67	75	68	36	232	85	131	147	242	111	407	145	90	181	241	233	118	28	34	24	109	209
Diversity (Species Richness)			2	6	6	6	4	6	4	12	8	11	10	14	10	13	9	10	11	12	14	11	7	4	7	7	12
Diversity (Simpson's Index for Diversity)			1	1.8	2.1	1.9	2.3	3.6	2.7	3.9	3.5	2.9	6.8	5.7	1.7	2.7	5.5	5.2	2.9	3.6	5.6	4.8	5.3	2.1	5.3	1.4	4.3

foraminifera in the well MITI Umaoi.

															4421.5m									
															Ishikari Group									
Globo. globosa- Cri. sorachiense								*Evolutinella subamakusaensis- H. crassiformis*																*1
4140	4180	4180	4200	4220	4240	4280	4280	4300	4320	4340	4360	4380	4400	4410	4420	4440	4480	4490	4500	4510	4520	4530	4540	4560
				1																				
55	20	12	25	17	8						1	32	7	4	1	1	14	1	4			1		
	13	7			5																			
		3	1								6	4		2					1		1	1		
	7	3	2																					
15	45	80	19	20	20				7	1	5	10	4	1		1	1	1		1	1	1	3	
1		1																						
1	2	9		7																				
		3	2																					
18	2	47	106	52	32	9	11	17	24	11		108												
6	2		2				2		1										1					
														1										
3	1												2			1	1							
14	5	8	6	3	3	2	3			11		6		3	2		1		2					
1																								
64	107	99	30	76	66	5	8	4	3	15	15	19	3	2			2		1					
			1	2			1																	
2																								
								2																
							1	1																
3							2																	
4	1	9	1	1	2																			
			1		1																			
						1																		
4																								
11	1	8	2	2					1				1											
					1		1																	
				1	2			1																
				2			1																	
	2		2			4			1	1														
8	14	7	13	4	2	10	1	1	3					1										
86	92	93	91	94	94	52	77	81	88	97	100	100	94	93	100	100	100	100	100	100	100	100	100	
0	0	0	0.5	1.1	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	8.1	7.5	8.9	5.3	5.8	48	19	19	13	2.8	0	0	5.9	7.1	0	0	0	0	0	0	0	0	0	
208	222	294	213	188	142	31	31	26	40	39	27	179	17	14	3	3	19	2	9	1	2	3	3	
12	10	9	8	9	7	2	6	4	4	2	3	4	4	4	2	3	3	2	4	1	2	3	1	
3.3	3.8	3.5	1.6	2.3	2.2	1	2.2	1.4	1.2	1	1.3	1.8	1.9	2.3	1	2	1.1	1	2		1	2		

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